ADDIS ABABA UNIVERSITY
SCHOOL OF INFORMATION SCIENCE AND SCHOOL OF PUBLIC HEALTH

M.SC IN HEALTH INFORMATICS PROGRAM

Laboratory Information System for Arada Health Center: Using a Design Approach

By: Debritu Kebede

A Project Submitted To the School of Information Science and School of Public Health for Partial Fulfillment of the Requirement for the Degree of Masters of Science in Health Informatics

June, 2017
Addis Ababa, Ethiopia

ADDIS ABABA UNIVERSITY
SCHOOL OF INFORMATION SCIENCE AND SCHOOL OF PUBLIC HEALTH
M.SC IN HEALTH INFORMATICS PROGRAM

Laboratory Information System for Arada Health Center: Using a Design Approach

By: Debritu Kebede

A Project Submitted To the School of Information Science and School of Public Health for Partial Fulfillment of the Requirement for the Degree of Masters of Science in Health Informatics

Advisors

Tibebe Beshah (PhD) _____ _____
Signature **Date**

Yimer Seid (MPH) _____ _____
Signature **Date**

Approved by Examining Board

Getachew Hailemariam (PhD) _____ _____
Signature **Date**

Mengistu Yilma (MPH) _____ _____
Signature **Date**

DEDICATION

This project work is dedicated to my beloved family, to my dad, Ato Kebede Mamo, my husband Mesfin Abebe, and my children's Robel, Ruth & Mathania for being my support of strength and for their patience when I devoted long time in my project work.

ACKNOWLEDGEMENT

First of all I owe my heart-felt gratitude to Almighty God, His mother Saint Virgin Mary, Saint George and all of His Saints for their being with me in every aspects of my life including this project work.

I am also indebted to my Advisors, Dr Tibebe Beshah and Ato Yimer Seid for their unreserved guidance, valuable and constructive, comments and inputs throughout this project work. Their Guidance and intellectual advices were my inspirations, without their help it would have been impossible to finish the whole project and I really want to thank you.

I am very grateful to Meseret Ayano coordinator of the Health Informatics Program for valuable guidance, facilitation and support during this project and throughout the entire program of study and many thanks also go to Arada health center manager, staff for willingly, gave their time for the interview in the requirement collection stage.

I would like to pass my deepest thanks to, Addis, Atkilt, Mebratu, Tigist , Solomon, Tadesse and Turifat who helped me one way or another during preparing and finalizing this project work.

Finally, I would like to thank my beloved family, my husband Mesfin Abebe, my children Robel, Ruth, Mathania and Burte for their love and support in all the times of my project. This accomplishment would not have been possible without them. Thank you.

Table of Content

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

AIDS	Acquired Immune Deficiency Syndrome
CDC	Centers for Disease Control
CHI	Canada Health Info Way
CMS	Central Medical Stores
CSS	Cascading Style Sheet
HER	Electronic Health Record
EMR	Electronic Medical Record
FMOH	Federal Ministry of Health
GFATM	Global Fund to Fight AIDS Tuberculosis and Malaria
HIT	Health Information Technology
HIV	Human Immune Deficiency Virus
HLISAG	Hospital Laboratory Information System Advisory Group
HMIS	Health Management Information System
ICT	Information Communication Technology
I/p	Insertion Parameter in the database
LIS	Laboratory Information System
NHL	National Health Laboratory
OO	Object Oriented
PEPFAR	President Emergency Plan for AIDS Relief
PHP	Hypertext Processer
SQL	Structured Query Language
SWOT	Strength, Weakness, Opportunity and Threat
TAT	Turnaround Time
USAID	United States Agency for International Development
UML	Unified Modeling Language

ABSTRACT

Background: The laboratory information system is a data processing and dissemination system used in the laboratory to deliver accurate and understandable results within a reasonable timescale as requested by physicians. The problem of manual system used in Arada health center makes it difficult to provide efficient and quality health service data and the lack of integration of data, organized test result, different reporting formats and long turnaround time brings about delay of treatment and poor data quality.

Objective: The objective of this project is to design and develop laboratory information system for Arada health center.

Method: This used a combination of qualitative purposive method and object-oriented system analysis and design methodology with the incremental approach which includes requirement collection, analysis and design phases. The design emphasized the structure and behavior of systems, which interacts different objects or class within the system. Requirement was collected using the following tools (interview and relevant document review techniques). Analysis and design of the proposed system was performed using the Use Case Diagram, Activity Diagrams, Class Diagrams, Deployment Diagram and Persistent Model.

Result: Considering the importance of the Laboratory Information System for the health center the researcher has identified the problem of ordering a number of laboratory test papers for the single patient, the long time for data retrieval, transcription error and illegible hand writing that has been encountered while using paper based documentation. After identification of the problem, laboratory information system has been developed and tasted so as to solve the identified problems.

Conclusion: The developed system solves the problem of data integration and can capture a number of laboratory test order forms with a single interface used by the physician and the laboratory technician in the exchange of information for ordering laboratory tests and receiving the results back to the physician. This makes the laboratory data to be easily manageable and accessible by health professionals and decision makers. Usability test has been done and discussion was made with users in order to determine functionality, effectiveness and acceptability of the project and almost all of the respondents accepted the prototype. Regarding the functionality, the system produces reliable data and hence avoids the problem that used to occur by the manual system.

CHAPTER ONE

INTRODUCTION

1.1 Background

Laboratory services are an integral part of disease diagnosis, treatment, monitoring response to treatment, disease surveillance programs and clinical research (1). According to ISO 2003 the medical laboratory (clinical laboratory) is defined as a "laboratory for biological, microbiological, immunological, chemical, immuno-hematological, hematological, biophysical, cytological, pathological or other examinations of materials derived from the human body. For the purpose of providing information for the diagnosis, prevention and treatment of disease in, or assessment of the health of human beings, and which may provide a consultant advisory service covering all aspects of laboratory investigation including the interpretation of results and advice on further appropriate investigation" (2).

Medical laboratories form the backbone of health systems, as test results are critical for diagnosing diseases, guiding treatment, determining drug resistance and identifying diseases of public health significance through surveillance (3).

Laboratory Information System (LIS) refers to the computerization of the laboratory system or automation of secretarial physical activities associated with the processing of laboratory results to improve accuracy and turnaround time of results. Automation of laboratory activities removes the element of manual reporting, increases productivity and allows access to display data for analysis (4).

The LIS also provides benefits for many of the users of a laboratory, like obtaining information with the click of a button rather than having to dig through files. Data of years can be kept easily without the need for traditional archiving. In addition the improvement of business efficiency, improvement of data quality, automated log-in, tracking and management of all laboratory activity, automated customer reports (Turnaround Time, Work Load), automated Quality Control, daily Quality reports and easily accessible the available data (5).

Despite their importance, laboratories in health services of developing countries are often under-resourced, resulting in inadequate infrastructure, poorly trained personnel and lack of standardization. Likewise, laboratory Services in Ethiopia has been given little attention until recent years. Funds and improved testing technologies were made available to laboratories after the HIV pandemic burdened medical facilities; however, several challenges to implementing laboratory improvement remain unresolved, such as the lack of adequately trained personnel, clearly defined responsibilities and well-established organization (3).

In traditional paper-based reporting systems, collecting and exchanging quality and timely health data remains a challenge, as the process can consume the time and attention of health workers who are meant to be providing services instead, and can result in inaccurate or incomplete data. Electronic Health Information Systems can help minimize time spent while recording data, this experience has been appreciated in the countries, such as the HIS shared across Southern African countries Botswana, South Africa, Mozambique, Ethiopia, Malawi and Tanzania (6).

LIS is a complex system that works to simplify and improve the efficiency of laboratory operations, minimize data entry and other transcription errors as well as deliver valid and reliable laboratory results to the client in a most efficient way. In addition, the system provides a platform for surveillance such as monitoring antimicrobial resistance following the utilization of retrospective data archived in the LIS database (4).

One of the most important aims of LIS is the integration of many different sub processes, bringing together, consolidating the efforts of potentially many individuals, and consequently speeding up the whole process. LIS can save considerable amounts of time and dramatically improve the level of data access for all stakeholders. This is where LIS can become extremely beneficial. The sooner the user is notified of a problem, the sooner that problem can be fixed and the less the solution will cost (7).

Implementing the laboratory information system had the benefits both the patients and staff by improving patient care, safety, and specimen handling processes for referred laboratory orders, improved specimen tracking and improved operational efficiencies (8).

Laboratory services are an essential component of quality health-care delivery. They can be utilized effectively at every level of the health-care system, including primary health care and point-of-care testing. Quality laboratory results are required to support clinical diagnosis, rationalize and monitor treatment, for epidemiological purposes, for the surveillance and control of diseases of public health importance, and to provide early warning of disease outbreaks. This Improves the accuracy of health information and promotes effective national health planning and management (9).

The study conducted in Ethiopia shows that indicators and information products are considered adequate but data management is very poor. Health information system lacks resources dissemination and use, as well as data sources coverage are also inadequate and the capacity of institutions to generate, analyze, disseminate and use health information differs amongst the health institutions (5).

Therefore, this project is designed and developed a Laboratory Information System for Arada Health Center to integrate processes and procedures generated from different laboratory units. These include microbiology, parasitology, virology, biochemistry, hematology, serology and immunology. This makes the laboratory data to be easily manageable and accessible by health professionals and decision makers.

1.2 Statement of the Problem

Laboratory is a place that is equipped with different instruments, equipments, chemicals and the like for performing experimental works, research activities and investigative procedures. Medical laboratory is one part of the laboratory that is equipped with various biomedical instruments, equipments, materials and reagents (chemicals) for performing different laboratory investigative activities by using biological specimens (whole blood, serum, plasma, urine, stool, etc) (10).

Currently most health centers are using manual system for their client care. The manual system imposes different problems in information gathering, analysis, process, dissemination and use of medical information. Some of the problems encountered in the existing system are: there is no standardized way of information flow and access, lack of organized test result, duplication

of client data , transcription error different reporting systems, poor data quality, long turnaround time (TAT) and brings delay of treatment.

The study conducted in Ethiopia states that indicators and information products are considered adequate but data management is very poor. Health information system lacks resources dissemination and use, as well as inadequate data sources coverage and the capacity of institutions to generate, analyze, disseminate and use health information differs amongst the health institutions. (11). An integrated, tiered, functional and sustainable laboratory system is necessary in order to address these health system needs.

Arada health center is one of the ten health centers found in Arada sub city of Addis Ababa city Administration and it is the most populated health center comparing with other health centers within the sub city. According to its annual plan, the health center planed to provide services to around 31,307 populations and it has huge manual patient data that is difficult to collect, analysis and retrieve data and change into information for decision. The laboratory test orders are performed manually with the available 7 laboratory professionals.

According to the federal ministry of health one of the transformation agenda is information revolution which entails a radical shift from traditional way of data utilization to a systematic information management approach managed by corresponding level of technology. Laboratory information system is one of the technologies of collecting, analyzing, disseminating and utilizing information in the health sector that can considerably contribute towards holistic transformation.

Although there is a government initiative to implement the laboratory information systems in high work load hospitals and regional laboratories, such as St. Paul's Hospital Millennium Medical College and Yekatit 12 Hospital Medical College. The system is very expensive in that it has been developed by polytech and chosen by Centers for Disease Control as the cost for developing the system is not affordable by the developing country. In addition the system performs very sophisticated laboratory services that cannot be easily adaptable to health center laboratories.

Thus proposing a appropriate laboratory information system that fits to existing structure at a woreda level is important as it will minimize transcription error, duplication of data, decrease turnaround time and brings quality of information that was used for evidence based decision making and to make results traceable back to the source.

1.3 Objective

1.3.1 General Objective

The general objective of this project is to design and develop Laboratory Information System for Arada health center.

1.3.2 Specific Objectives

The specific objectives of this project are:-

- To empirically identify and assess challenges in the existing system.
- To model and design Laboratory Information System.
- To implement the proposed system.
- To evaluate the developed system.

1.4 Scope of the Study

The scope of this project focused on the designing and developing of Laboratory information system for Arada health center. Therefore, the project is set the scope to tackle the problem by assessing the existing situation of the health workers and health facility information system and identify user and system requirement. After identification of the system requirement analysis, description was made using the use case model. The designing process of the system is continuing using the UML (Unified Modeling Language).

The project was designed and developed between December1/2016 to May2017Gc.

1.5 Significance

The laboratory information system (LIS) is a computerized data processing and dissemination technique used to deliver accurate and understandable results. This system is not available in the majority of health centers found in Addis Ababa city administration especially in Arada sub city. Quality of recording and documentation has a significant contribution to the continuous

improvement of health services in general and laboratory services in particular. Since the primary goal of the health center is to give quality and efficient service for patients. The project is important for the institution and the clients for solving the problems occurred due to manual based recording and documentation by tracking patient record, minimize turnaround time, prevent records from damage or loss, reduce manual transcription error and produce quality report.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

Manual reporting systems are neither accurate nor timely. They depend on multiple transcription of results, they are slow, bulky and labor-intensive, data retrieval becomes a follow across multiple locations for a single piece of paper, and retrospective data analysis is virtually impossible (3).

Laboratory quality can be defined as accuracy, reliability and timeliness of reported test results. If inaccurate results are provided, the consequences can be very significant, including: unnecessary treatment, and complications, failure to provide the proper treatment delay in correct diagnosis and additional and unnecessary diagnostic testing (4).

2.2 Information System

Information systems have been the dominant application area of computing as well as Organizations large and small, private and public have come to rely on information systems for their day-to-day operation, planning, and decision making. Effective use of information technologies has become a critical success factor in modern society (12).

Information and Communication Technologies (ICTs) have been defined as “any product that will process, store, manipulate and communicate information electronically in a digital form” while ICTs are crucial to facilitate data management, evidence based decision-making and clinical communication, Health information technologies are critical to improve the efficiency and effectiveness of healthcare management. (13)**.**

Furthermore Information System studies the uses made of ICT within human organizations and societies. ICTs are applied to improve the way organizations operate and to help people to do their jobs. This is principally achieved by collecting, storing, processing and sharing data and information. According to Harold Leavitt there are four perspectives: the perspective of

technology, the task it is applied to, the people who use it or the organizational or social structure. We could choose to take just one of these perspectives. However, these four elements are all in relation to one another, we usually need to consider more than one, and sometimes all of the four perspectives (14).

There are eight areas in which ICT can contribute to health care which have been identified in ICT and Health newsletter: access, effectiveness, efficiency, quality, safety, knowledge generation, economic impact and integration. Each of these applies to the specific areas in which the technology is used: prevention, diagnosis, treatment, monitoring, health education, management of services and health-sector e-commerce. The benefits and positive externalities of the technologies affect not only patients and the general population, but also health professionals and, due to their effect on economic growth, the society at large (15).

Appropriate health information resources are needed to support informed health professionals. Various scholars agree that ICTs are invaluable for accessing, retrieving and circulating recent and relevant information among health professionals. Even though ICTs are important for efficient healthcare systems, adoption rates are still very low in resource-limited countries and healthcare facilities in developing countries often experience poor data management, weak evidence-based decision-making practices, high medical errors and poor planning (13)**.**

Information systems have become the backbone of most organizations and play a prominent role in almost every sector: education, finance, health care, manufacturing, and large and small businesses. In every day work, communication, information gathering, and decision making all rely on information technology (16).

2.2.1 Health Information System

Health information systems refer to any system that captures, stores, manages or transmits information related to the health of individuals or the activities of organizations that work within the health sector. Overall, a well-functioning HIS is an integrated effort to collect, process, report and use health information and knowledge to influence policy and decision-making, program action, individual and public health outcomes, and research (5).

According to Goldschmidt, 2005 Health information technology is the application of information processing involving both computer hardware and software that deals with the storage, retrieval, sharing, and use of health care information, data, and knowledge for communication and decision making (17).

In most developing countries health information systems are woefully inadequate to provide the needed information support. There is a need by the health sector of developing countries to use the limited resource effectively in order to provide an efficient and equitable Health service to the communities this requires sound management that is based on information, which is crucial at each level of the health service management. Correct and up-to-date information is critical, not only for the provision of high-quality clinical care, but also for continuing health care, maintaining health care at an optimal level, clinical and health service research, and planning and management of health systems (5).

The health information system provides a remarkable support for decision-making and has the following four key functions: data generation, compilation, analysis and synthesis, and communication and use. The health information system collects data from health and other relevant sectors, analyses the data and ensures their overall quality, relevance and timeliness, and converts the data into information for health-related decision-making (18).

Health information system (HIS) is the intersection between healthcare's business process, and information systems to deliver better healthcare services. The use of ICT in healthcare organizations has grown in the same pattern as compare to the larger industry landscape. The nature of healthcare industry, which is highly influenced by economic, social, politic, and technological factors, has changed over time (17).

2.3 Information System Development

Systems development is the entire set of activities needed to construct an information systems solution to a business problem or opportunity. A key component is information systems planning, which begins with the strategic plan of the organization (19). Information system development is the systematic description, explanation and evaluation of all aspects of methodical information systems development (20).

A system development methodology refers to the framework that is used to structure, plan, and control the process of developing an information system. A wide variety of such frameworks have evolved over the years, each with its own recognized strengths and weaknesses. One system development methodology is not necessarily suitable for use by all projects. Each of the available methodologies is best suited to specific kinds of projects, based on various technical, organizational, project and team considerations (21).

2.3.1 Contemporary Modeling Approaches

The contemporary view of software development takes an object-oriented perspective. In this approach, the main building block of all software systems is the object or class. A modeling is a language whose vocabulary and rules focus on the conceptual and physical representation of a system and standard language for software blueprints (22).

There are different modeling approaches such as, structured and object-oriented, can be used in information system development.

2.3.1.1 Structured System Analysis and Design Approach

The processes used by analysts in determining information requirements were more comprehensive than the literature on structured systems development approaches (23).

This system is the traditional view of software development. This view leads developers to focus on issues of control and the decomposition of larger algorithms into smaller ones. As requirements change and the system grows, systems built with an algorithmic focus turn out to be very hard to maintain (22).

2.3.1.2 Object-Oriented (OO) System Analysis and Design Approach

A software component that can be easily modified in small ways, this modification can be done to change both functionality and design. This allows for systems to be more adaptable. Improving the design through incremental change is accomplished by refactoring, again a concept that owes its origin to the development of the object-oriented approach (24).It permit the links specified by associations to be used in a more flexible and general way (22).

2.4 Laboratory Information System

Laboratory information system (LIS) is a data processing and dissemination technique used in the laboratory to deliver accurate and understandable results within a reasonable timescale as requested by clinicians. The system entails a sequence of events which include, delivery of samples to the laboratory, sample accessioning, analyzing, verifying and approving results or reanalyzing samples and releasing results to the clinicians who requested the tests. Automation of laboratory activities removes the element of manual reporting, increases productivity and allows access to retrospective data for analysis (25).

Existing laboratory data management needs to be upgraded to a level that is sufficient to improve laboratory data quality, reduce the manual data entry work done by laboratory technicians, and aid in timely and routine reporting of disease trends. In such circumstances, an LIS that works well in resource-limited settings, reduces the dependence on paper-based systems and adapts well to varied work flow practices is a critical requirement. Factors such as customizability ease of use and early and constant involvement of the target laboratory staff are also key to ensuring That any new system is sustainable and addresses the needs of the laboratory staff and technician (26).

The product of the laboratory information is primarily in the form of test reporting information (data) needs to be carefully managed to ensure accuracy and confidentiality, as well as accessibility to the laboratory staff and to the health Professional. To shorten turnaround time of lab tests, to improve access to the results database and to improve productivity it is also an indispensable tool for both the analyst and the lab manager as it tracks samples. It documents and summarizes resource utilization within the laboratory, again as a follow-up from the basic process of recording request details on the database (4).

Electronic laboratory information systems (LIS) have become key components of clinical and public health laboratory infrastructure in developed countries. In resource-limited laboratories of the developing world, such systems are at the earliest stages of development and test samples and results related data are largely managed by non-standardized paper-based systems and manual

entry methods. Due to this, the burden of record-keeping hampers laboratory staff from focusing on performing tests (26).

The LIS Solution reduces paperwork, errors and uncertainty. It speeds things up, such as faster releasing of production orders and the time frame between identification of an engineering challenge or task and resolution becomes easier to reliably forecast. Laboratory Information System (LIS) is a software-based laboratory and information management system with features that support a modern laboratory's operations (27)**.**

The modern laboratory exists in an environment that produces a large amount of data with the beginning of new technologies. Both the quality and quantity of information is increasing exponentially that can cause significant problems and this need to be managed by LIS (28)**.** The LIS also provides benefits for many of the users of a laboratory, like obtaining information with the click of a button rather than having to dig through files. Data of years can be kept easily without the need for traditional archiving. In addition the improvement of business efficiency, improvement of data quality, automated log-in, tracking and management of all laboratory activity, automated customer reports (Turnaround Time, Work Load), automated Quality Control, daily Quality reports and easily accessible the available data (5).

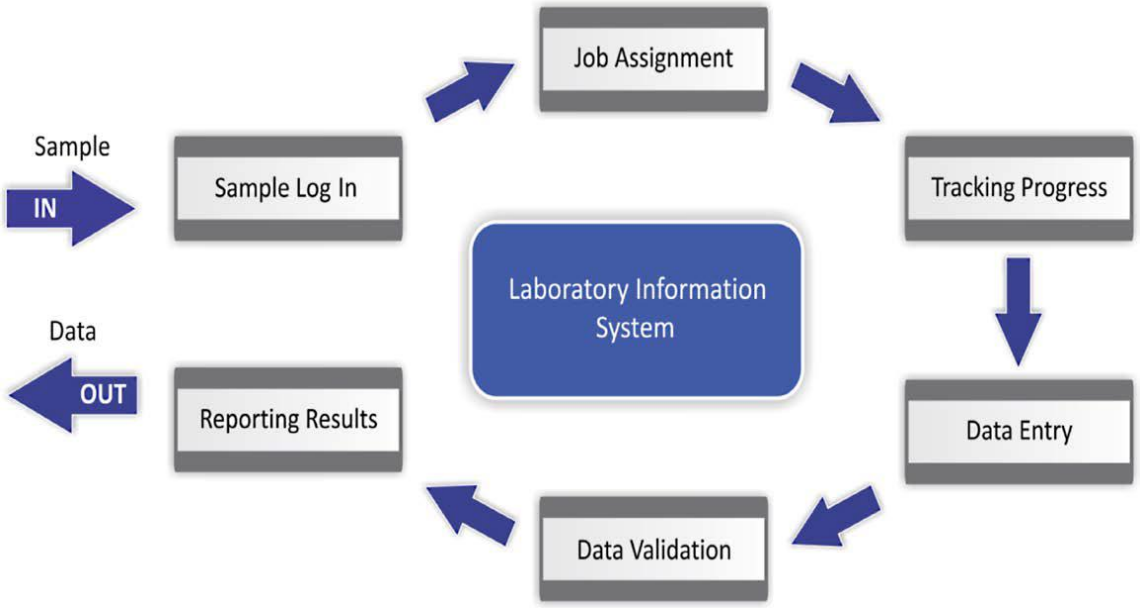


Figure 1: Laboratory information system processes and procedures (25).

2.5 Related Work

Study conducted in USA by using the 2007 Healthcare Information and Management Systems Society (HIMSS) Analytics Database over 5,000 US healthcare organizations and provides extensive data on the hardware, software, and information technology infrastructure within healthcare organizations mentioned that laboratories play vital healthcare service roles. During the study period, laboratory tests accounted for 60-70 percent of all information used in clinical decision-making Laboratory Information Systems (LIS) which are complex and include automated processes that interface with host information systems, other integrated clinical information systems and electronic medical records (EMRs). The automated laboratory processes reduce technical errors, promote productivity and support high performance work processes that allow greater efficiency with increased testing volumes (29).

The Study conducted in Canada have identified existing laboratory information exchange projects and network via HLISAG membership that describes Laboratory Information Systems (LISs) are the infrastructure backbone for clinical laboratory operations.LIS integration that have been used by organizations, each supporting their specific needs. Among the regional initiatives surveyed, the identified benefits included: reduced turnaround time, reduced test duplication, decreased transcription errors, improved access to patient information and a reduction in time-consuming manual processes (7)**.**

A study conducted in United Kingdom showed that implementing LIS is an extremely expensive process which must be improved considerably if it is to become more widely available. There exist many technologies of which to take advantage however, there are very prominent risks involved in the implementation of LIS. A high failure rate can deter many laboratories from attempting such a project. Even if there are various ways to reduce this risk of failure but none of the afore-mentioned processes provide a total ideal solution (8).

Different researches have shown that many countries in Africa, clinical laboratories perform timely, accurate diagnostic testing services and disease reporting to Ministries of Health for surveillance, prevention, and control and outbreak response. However, resource limitations and high demand for diagnostic testing services often limit the contribution of clinical laboratory data

for surveillance purposes. Test result reporting may be delayed, may not be accurate and may not provide information on priority health issues (30).

According to the study conducted in Nigeria using the PEPFARS initiative through USAID (United States Agency for International Development) and GFATM (Global Fund to fight AIDS Tuberculosis and Malaria) shows that laboratory test results play an important role in the diagnosis and treatment of disease processes. When combined with the history, physical examination, x-ray studies and other diagnostic procedures, laboratory diagnoses always lead to sound medical diagnostic judgments. The importance of quality in the function of health care laboratories is recognized worldwide and poor quality laboratory results can lead to misdiagnosis and wrong treatment (31).

Health systems in developing countries with limited infrastructure are particularly vulnerable to deficiencies in all stages of laboratory testing from sending and tracking samples, to ensuring accuracy of results, to getting results back to the clinician. The study conducted in Peru by using e-Chasqui for reducing the time to communicate patients' test results, to start them on appropriate treatment, and to achieving culture conversion states that laboratory information system used for diagnosis and management of many diseases requires timely, reliable access to laboratory investigations (32).

Study conducted In Botswana by the Ministry of Health (MOH) of Botswana in collaboration with the Ministry of Local Government (MOLG) for the provision of quality laboratory testing services with support from partners including BOTUSA, ACHAP, CHAI and Botswana Harvard Partnership, have shown that standardization effort seeks to strengthen laboratory capacity in Botswana. It is believed that the best way to do this is by building sustainable laboratory capabilities that will provide access to high quality, rapid, and affordable diagnostic tests for the care, treatment, prevention and surveillance of HIV/AIDS, tuberculosis (TB) and malaria amongst other diseases (33).

According to the study conducted in Kenya by kenyatta national hospital comprehensive care centre, electronic laboratory information systems have the potential to improve patient care and public health monitoring. Some of the challenges experienced in health facilities, such as misfiling, transcription errors, double allocation of patient numbers are obstacles that a well-

designed information system can overcome the problem. However, creating well designed information system is a difficult task necessitating appropriate resources, expertise and time to be successful. The web-based laboratory information system for KNH CCC met its objective of ensuring efficient and timely availability of accurate test results to the clinician, as a critical component of the overall process of patient care. Therefore, the content the laboratory delivers makes it critical to patient safety, quality of care, and speed to diagnosis. Comprehensive Care Centre (CCC) which provides care and support to PLHIVs has in house laboratory services but have had challenges associated with manual handling of results such as loss and misplacement of patients' laboratory results leading to delays in diagnosis and treatment (34).

According to the study conducted in Ethiopia on data exchange interoperability framework For Laboratory Information System (LIS) and Electronic Health Record (EHR) of two hospitals in Addis Ababa, states that eHealth applications in the hospitals should consider on how to make them communicate and in order to address major challenges such as lack of interoperability, create fragmentations and data redundancy on eHealth applications, laboratory result lost and transcription errors, it also create workload because working in both in paper based and electronic through EHR and LIS (35).

According to the study conducted in Ethiopia on designing an electronic medical record system for Amanuel hospital, shows that integration of people, hardware, software, data and procedures which are the five basic components involved in the smart care electronic medical record system is essential for its sustainable adoption in the laboratory department (36).

In Ethiopia Polytech Laboratory Information System has been chosen by the Centers for Disease Control (CDC) as the standard Laboratory Information System for the United States' PEPFARS initiative for HIV/AIDS relief in Ethiopia. The system is used as the standard laboratory information system which can be interfaced to all of analyzers commonly found in modern clinical laboratories. This system is deployed in 20 hospital and regional laboratories that supports work and information flow in all steps of the laboratory testing process, including patient registration, test ordering, and sample collection, testing, and reporting the result (10).

As the related literature reviewed shows that the problems identified in the laboratory service of Arada health center are common to all countries health services using manual system. It is also observed that those countries implemented laboratory information system had effectively overcome the problems due to manual system that are identified in this study.

Generally, all the literature reviewed focused on the importance of laboratory information systems to improve access, quality diagnostic testing and provide accurate, timely information for patient care, public health planning and policy decisions. Hence implementing the LIS developed by this project in the health center will bring deference in the efficiency of the health service.

CHAPTER THREE

METHODS AND MATERIALS

3.1 General Approach

Generally a qualitative study combined with a design oriented approach was used and the system used iterative (incremental) approach following an object-oriented system development. The basic idea behind an iterative object oriented design is to develop a system through repeated cycles and in smaller portions at a time (incremental).

3.2 Study Population

The study populations were health professionals, higher officials and data clerk working at Arada health center. With respect to qualitative purposive sampling technique was used to select 15 respondents for the reason that they have direct contact with the laboratory activities. In addition, document review like registration book, laboratory test request paper was used as source of the study.

3.3 Data Collection Methods and Process

In this project different data collection methods were used to collect requirements, such as interview and document analysis, laboratory test order form, result registration log book and report format. Based on the interview and document analysis result this project identified business and system requirements. The principal investigator was responsible to collect the data.

Interview

Interviews for requirement gathering were conducted to the selected project population. The interviews used went through separate interview guide for each interviewee based on their status. The responses of the respondent were record in audio and at the same time verbatim notes were taken to capture all the ideas, opinions, experiences dictated by the interviewee. This is important input for designing the laboratory information system. The interview was conducted with higher

officials, health professionals and data clerk who have direct contact to the laboratory department. The interviews were carried out by the project investigator. Myself.

Document Review

The researcher reviewed different types of documents. This review has been done for the purpose of knowing exactly what test request forms, log books, and reporting formats that the laboratory department is currently using as well as to know the specific information that has been included and missed.

3.4.1 Data Analysis Methods

An inductive approach was applied to collect the requirement. Data were collected, organized and reading through all the data were made so as to understand the collected data from higher officials and health professionals who have direct contact to the laboratory. This approach has been used as it provides an easily usable and systematic set of procedures for analyzing qualitative data that can produce reliable and valid findings.

3.4.2 Requirement Analysis and Design

Three steps of requirement analysis were followed; understand the existing situation, identifying improvements and defining requirements for the new system. After requirement was captured using the data collection tools, The result of the system modeling that helps to understand the system models that are used for analysis of the system was done using the :-

Use case diagram: is a graphic representation of the interactions among the elements of a System.

Class diagram: describes the structure of a system by showing its classes, attributes, operations and relationships between objects of the system.

Activity diagrams: are graphical representations of activities and actions with support for alternative, iteration and concurrency. Activity diagrams show the general flow of management.

Deployment diagram: is that shows the configuration of run- time processing nodes and the artifacts that live on.

Persistent model: persistence is the ability of an object to survive the lifetime of the operating system process in which it resides.

3.5 System Modeling and Designing

This project was employing Object Oriented design approach to design Laboratory Information system of Arada health center. This method is used in order to design the system interacting patient, health professional, laboratory investigation and report within a system.

3.6 Analysis and Design Tools

After having all the required data and information, different designing and programming tools has been used:

Frontend (in the Client Side):

Joomla: was chosen in the Client Side because its nature of flexibility, supported on all browsers, user-friendly, consistent and efficiency and it is free.

CSS: was chosen in the Client Side because it is designed primarily to enable the separation of document content from document presentation, including aspects such as the layout, colors, and fonts and basically designs.

Backend (in the server side):

PHP: was chosen in the server side because it could be implanted into HTML and it uses as link to connect the html with the database. It could be opened with any browser and it could easily be connected to most databases.
MySQL: database server was used because it is an open source, easily accessible and compatible with the above applications

The applications used to design the system were:

Adobe Dreamweaver: was used for the designing of the prototype.
Microsoft Visio 2007: for drawing various modeling diagrams.
Microsoft office: for documentation purpose.

Xampp server: to access the MYSQL Database.

Table 1: Techniques, Tools and Method

Phases of the software development	Techniques	Tools	Methods
Feasibility, requirement gathering /planning phase	• Interview • Document review	• interview • document analysis • literature review	Incremental/ Iterative development approach
Analysis phase	• Narrative Analysis • Software Specification Models(UML)	• Microsoft Visio 2007	
Design for the new system	• Object oriented & design(UML) • User interface design	• Microsoft Visio 2007	
Construction of the new system	• Object Oriented • Programming	• HTML, CSS • PHP • MY SQL	
Evaluation & Testing	• Acceptance Evaluation • Descriptive state	• user test checklist	

3.7 Evaluation and Testing Methods

After designing the system, prototype was developed and then its system performance is evaluated to see the functionalities of the system followed by user acceptance test so as to evaluate the usability of the system. For this process user test checklist is used.

3.8 Methods of Dissemination of Results

After the study is completed, the report will be forwarded to Arada health center where the study was conducted and to AAU as partial fulfillment of M.Sc degree in Health Informatics.

3.9 Operational Definitions

Lab tech: represent a person who performs laboratory activity.

Timely Reporting: the reporting period that is assigned by HMIS for the activity performed from 21-20 and sending the report not later than the 26th of the month.

3.10 Ethical Consideration

Prior to data collection, ethical clearance was obtained from School of Public Health and school of Information Science of AAU to conduct this project an official letter was provided to Arada health center. In addition, concerned bodies and staffs in the health center were informed about the objective of study, consent forms were delivered and all interviewees were asked their willingness to participate in the requirement gathering. Besides, the convenience, confidentiality, privacy and comfort of the participants were considered.

CHAPTER FOUR

ANALYSIS AND DESIGN OF THE SYSTEM

4.1. Overview

Data collection and requirement analysis is one of the basic steps in the software development life cycle. The data collected from Arada health center professionals and higher officials as well as the experiences of the other researchers taken from the literature used as the base of analysis in this project. In this chapter the existing system, the business process, the functional and non-functional requirements, the system modeling and the design of the new system are presented.

Here are some points in response to the questions: regarding the challenges in the laboratory, there is a problem of ordering a number of laboratory investigation papers for a single patient, having long turnaround time, loss of laboratory result paper, illegible handwriting, and contamination of laboratory result paper with laboratory samples. The laboratory information is being communicated in such a way that the patient takes the investigation paper to the laboratory and brings the results back to the physician. The information is being retrieved using the medical record number from the laboratory registration book and coming to the annual plan to develop the laboratory information system (LIS), the health center is proposed to incorporate the LIS in the next year plan.

4.2. Description of Existing Systems

4.2.1 The Work Process and Forms Used

Currently in Arada health center there is no an automated laboratory information system. The patient data is being exchanged and information processed using manual paper based. When a patient arrives at the departments, for example at outpatient department, initially a physician fills the patient history or information into the outpatient department form, and diagnosis the problem. According to the diagnosis; the patient gets treatment and the treatment and diagnosis information is registered on the patient card manually. The overall business process description

of the two departments is presented as follows. Even though there are different departments in the health center the communication between Outpatient department (OPD) and laboratory department is more frequent than the others.

4.2.1.1 Major Business Process

Outpatient department business process:

- The patient arrives at the outpatient department with patient card.
- The physician performs the chief compliant activities from the patient.
- The physician takes/registers the history of present and past illness which includes family history and patient history.
- After the patient examine and diagnose, if further investigating required the physician order laboratory investigation. According to the result the physician prescribes medication.
- If the patient doesn't need laboratory investigation the physician prescribe medication and appoint the patient to the next visit. Finally patient card is archived.
- Report from the outpatient activities generated monthly quarterly and annually.

Laboratory department business process:

- The patient comes to laboratory department with laboratory test order.
- The receptionist accepts the laboratory test order and asks the name of the patient from which department he/she came.
- The receptionist explains to the patient about the sampling (from where to take, why the sample needs and other related information) and takes sample.
- The receptionist tells to the patient to come back after some time to take his sample result.
- The receptionist registers the test order form which includes the department, name of patient, sample id, date and type of test.
- The receptionist distributes the sample to the lab sections (chemistry, parasitology, urinalysis, hematology, and serology).
- Each section performs quality check of the machine or regent status.

- The laboratory technician in the section checks sample quality whether the sample mix for example urine mixes with a stool and so on.
- The laboratory technician examines sample and the result cross checked or review.
- The result records on the request form and on a log book then send back to the receptionist.
- The receptionist checks, the test result and gives to the patient when the patient comes.
- Report from the laboratory department generated monthly, quarterly and annually.

4.2.1.2 Strength, Weakness, Opportunity and Threat (SWOT) Analysis of Arada Health Center

In addition to the business process description a discussion on SWOT Analysis was help for better understanding of the whole system. Accordingly the following SWOT Analysis is presented based on the physical investigation conducted on the health center. There were different questions raised during requirement gathering, such as "*does the health center have a plan to develop laboratory information system?"* in regard to this question, the health center higher officials responded that the LIS will be incorporated in the next year plan. The other question was *"is the laboratory activity being reported timely?"* in response to this, the higher officials said that the laboratory activities are not being reported timely as the activities are registered using the logbook and also there is a need to further counting using the tally sheet that causes the health center to cost additional time as well as leading to human error during counting of cases.

Table 2: SWOT Analysis of Arada Health Center

Strength	**Weakness**
• An organized ICT infrastructure • LIS implementation is incorporated in the next year plan • There is a backup electricity system • Support from health center management committee	• Lack of computer trained personnel • Poor information retrieval system • Ordering a multiple of laboratory investigation papers for a single patient • long turnaround time • loss of laboratory result paper • Illegible handwriting
Opportunity	**Threat**
• The availability of national plan on information revolution • The availability of LIS in different governmental hospitals • Government commitment • Regional health bureau support	• Budget scarcity • Concern of sustainability of national LIS guideline • Low supportive supervision from FMoH, Regional health bureau and also from the sub city

4.2.1.3 Forms and Documents used in the Existing Laboratory System

In the existing system different kinds of forms and documents are used to manage patient information this forms was carefully examined in the analysis phase the forms used in the existing system in data entry are:

Registration form: this form is used to record patient personal information and address. It is filled by data clerks.

Laboratory request form: It is used for requesting the laboratory investigation by the physician and also receiving the result from the lab.

Log book: In the laboratory department there are different types of log books in each unit used to register investigation results.

4.2.2 Identified Problems from Existing Laboratory System

According to the requirement analysis, different problems were identified and the cause for the problems were due to the health center's using of paper based recording as this leads to less security of the data, takes long space to archive and easily damageable as well as taking long time to retrieve the patient record. some of the problems identified were; loss of some patient records, multiple request form which is time taking to fill, the impossibility of accurate and timely reporting as the tally sheet is being used that lead to human error during counting of cases, poor data quality like incompleteness of data, long turnaround time (TAT), illegible hand writing in records (Transcription error), contamination of result paper, lack of confidentiality in storing and retrieval of patient data.

In response to the importance of the new system the managers and health professionals reflected that the proposed Laboratory Information system would have a great importance to solve the problem that is being occurred while using paper based system.

4.2.3 Infrastructure in Place

The health center has a total of 20 desktop computers in different offices. There is only one computer in laboratory department, two computers in the patient registration room, one computer at outpatient department and the remaining is found in offices. The officers use the computers majorly for browsing internet and Microsoft Excel based report writing. The aforementioned findings are obtained from the interview done on the existing system. This investigation on the existing manual system helps to identify the opportunities, problems and also will help to understand the business domain of the organization. For the purpose of keeping the Focus with in manageable scope the following table provides detail of only hardware in the Registration, outpatient and laboratory department.

Table 3: Types Hardware in Each Department

Department	Type of hardware	Quantity	Brand and model	Processor (GHL)	RAM (GB)	Hard disk (GB)	Purpose of the computer
Registration	Computer	2	DELL	Dual 2.93 GHz	1.94	160	To register Patient personal information
	Printer	-	-	-	-	-	
Outpatient	Computer	1	DELL	Dual 2.49 GHz	2	160	To prepare report
	Printer	-	-	-	-	-	-
Laboratory	Computer	1	DELL	Dual 3GHz	2	160	To prepare report
	Printer	1	HP Lazer jet p2055d	-	-	-	

4.3 The Proposed System

The existing system has the above listed problems and hence, the proposed system has been designed to overcome the drawbacks found in the existing system possible to retrieve patient information easily. Reduce error due to illegible hand writing (Transcription error), the archived document space consumption. The report generated from the system enable a sound decision making by the health care providers and decision makers. The system works on computers using local area network in line with the requirements of departments. There is a centralized database to store patients' data as well as to integrate the Units (Out Patient Department & Laboratory units).

4.3.1 Requirement Gathering and Analysis

The purpose of requirement gathering and analysis is to define what the new system should do. Since the system was built based on the information gathered in this step, any errors made in this stage was result in the implementation of a wrong system.

4.3.2 Functional Requirements

Functional requirements are requirements which are vital in identifying which stakeholder in the system needs which types of information in what format. These requirements mainly address what has to be performed by the system. It involves identifying the basic businesses, performances/ functionalities that a system should provide to users and a task that must be done

by the system (24).The different functional requirements that are required to be performed by the system to be built are listed below. The lists are obtained by the careful face to face interview and document review of the different process and functionalities that are found in the existing system.

F1 - The system should authenticate the user and assign privileges according to the assigned rights

F2- The system enable searches patient.

F3- The system should enable users to register patient information and updates patient and user information.

F4- The system registers patient laboratory test order.

F5- The system records patient laboratory test result.

F6- The system enables generates report.

F7- The system should allow the user to be able to maintain the account.

4.3.3 Non Functional Requirements

A nonfunctional requirement describes user behavioral properties that the system must have such as performance and usability. The non functional requirements correspond to the process of explaining the features, characteristics, attributes, and constraints of the information system used to limit the boundaries of the proposed solution (37). The following are the non-functional requirements of the proposed system:

Security: Since the system is going to handle personal information which is confidential, it should give access to only the once that have login information's and deny access for the once without login information.

Availability: - Since the health center gives services for 24 hours, the system should be available 24 hours/day or 7 days a week. In addition the system should use English language since it is difficult to translate the diagnosis and medication of illnesses.

Maintainability; the system should be maintainable by the developer as well as other authorized trained person. The system should also be modifiable at any time to enhance features based on the office needs. The system could be improved by adding new functionalities without necessarily changing the basics. These issues should addressed by availing modular functionality, user guideline and detail design documentation, therefore the developer as well as authorized trained person can modify or upgrade the system easily.

Error handling; - the system is expected to handle errors encountered during run time. Errors could arise from users and from the system. Errors that occurred from the wrong doing of users will be handled by appropriate exception handling mechanisms.

User interfaces; - Since the system involves users with different technology awareness and usage capability the user interface should be able to support this usability needs. The system is going to be used by different user categories, it should have a very simple and user friendly interfaces for everyone to understand the functionalities easily. Since the system is copied and have similar features like the paper based, it should be easy to use.

4.3.4 Analysis Model

Modeling is an important in everyday human activity. Models help us to understand a complex world by focusing on those properties of "reality" we are currently interested. The goal of modeling is to develop as simple as possible model of the reality that still correctly reflects all important and interesting aspects. In software development, we build models of software systems to enable us to better understand the systems we are developing. In object-oriented modeling, we focus on the types of objects manipulated by the software systems. UML model are used in the analysis of the system. The Unified Modeling Language (UML) is a language for specifying, visualizing, constructing and documenting the artifacts of the systems (38).those models are: use case model and activity diagram.

4.3.4.1 Use Case Modeling

A use case describes a certain piece of desired functionality of an application system. Use cases make it clear what a system is going to do and by intentional omission what it is not going to do.

It is constructed during the analysis stage. It shows the interaction between an actors, which could be a human or a piece of software or hardware and the system. It does not specify how the system carries out the task (39)**.** Requirement analysis has been done using document review and interview with the staff that has directly contact with the laboratory department and come up with the identification of the following use cases.

Identified use cases in Arada health center

1. Login
2. Register Patient
3. Search Patient
4. Update Patient Record
5. Order Laboratory Test
6. Laboratory Test Result
7. Generate Report
8. Manage User Account

Actor of the Existing System

Actor represents a person or an organization that has a major role on the overall process of the organization. The main Actors identified in the existing system are as follows:

Table 3: Identified Actors and Their Description

No	Identified Actors	Description
1	Physician	Refers to a health professional who diagnose and treat patient.
2	Laboratory technician	Refers to a person who perform laboratory test.
3	System administrator	Refers to people who administers the system and maintain user account.
4	Data clerk	Refers to a person who performs patient registration.

Use Case Diagram

Use case diagram is a simplest illustration of interactions of actors of the system showing relationships of actors with uses cases of the system while describing the main actions performed in the system. The use case diagram shows the boundary of the system and it is a representation of a user`s interaction with the system and depicting the specification of a use case (40).

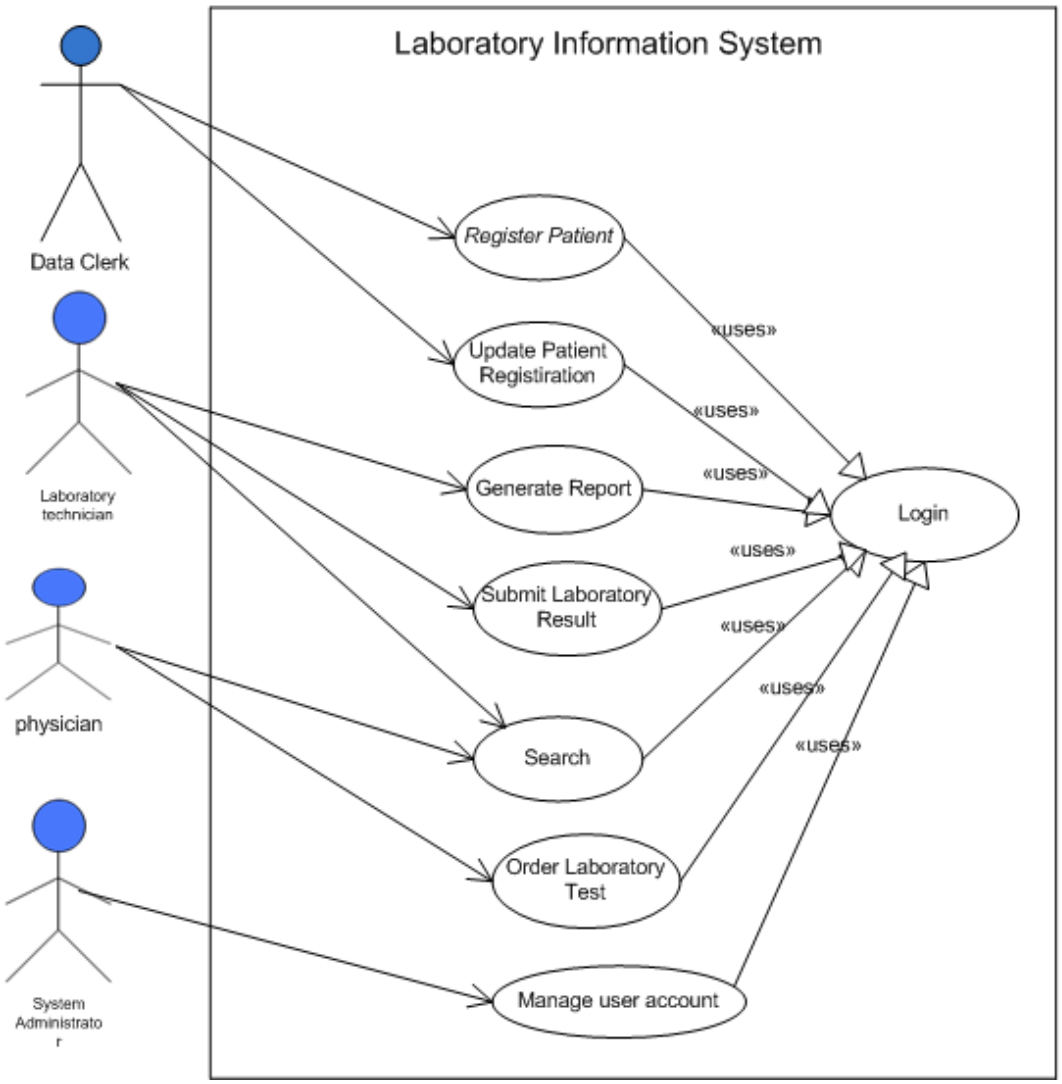


Figure 2 System Use Case Diagram

4.3.5.2 Use Case Documentation

Use case description is a textual representation of the course of events encountered when an actor is interacting with the system. Use case narratives are the next and most important modeling standard, which describes each use case in detail as a path cross through the system to meet a requirement. For the later technical steps, use case narrations play the role of where to start. So, the more precise and complete a use case narration is, the more accurate will be the later designs like class diagrams (40). The description of each use case is listed below:

Table 4: Description of Login Use Case

This use case is required to meet F1 requeriment I mentioned on the functional requeriment section

Use Case ID	UC_1
Use case Name	Login
Use case description	Used to allow Actors of the system to get in to page with Authentication.
Primary actor	Physician, Laboratory Technician, System Administrator and Data Clerk.
Pre-condition	The user must have user name and password
Post- condition	The user logs into the system
Main success scenario	1.Users wants to login 2. The system responds by presenting the home page along with the login form. 3. The user enters username and password in the login form. 4. The system validates the user. 5. The system display home page for the privileged user. 6. The use case ends.
Alternative path	4a. If the username or password is not valid, an error message is displayed. 4a1. The user clicks an ok button. 4a2. The user is returned to login screen and re enters user name and password.

Table 5: Description of Search Patient use case

This use case is required to meet F2 requeriment I mentioned on the functional requeriment section

Use Case ID	UC_ 2
Use case Name	Search a patient
Primary actor	User (Data Clerk, Physician ,Laboratory Technician)
Summary description	This describes how the user searches information from the system to view or modify or update patient information.
Precondition	The user is authenticated.
Post condition	The user gets the information what he/she needs.
Main success scenario	1. The user wants to search patient information. 2. User enters the patient card number, name on the search bar. 3. User clicks search button. 4. System displays the searched patient's information. 5. Use case ends.
Alternative path	2a. If the user makes error while enters the card no, Name or the system displays error message. 2a1. The user clicks ok button. 2a2. The system inform the user to re-enter the information

Table 6: Description of Register Patient Use case

This use case is required to meet F3 requirement I mentioned on the functional requirement section.

Use Case ID	UC_3
Use case Name	Register Patient
Primary actor	Data Clerk
Summary description	This Use Case describes the process of how the data clerk enters personal information of the patient into the registration system.
pre condition	The data clerk is authenticated.
Post condition	The patient is registered on the system.

Main success scenario	1. The data clerk wants to register patient information. 2. The systems display the registration form. 3. The data clerk enters the name or demographic information of the patient and search. 4. The data clerk confirms that the patient is not registered in the system. 5.The data clerk enters the data (patient personal information and address) 6. The system checks the entered data and compares with data restriction. 7. The system validates the input data and registers the patient. 8. The system automatically generate patient ID and the data clerk click submit button. 9. The data clerk save the record in the system. 10. The Use case ends.
Alternative path	4a. If the patient is already registered or repeat. 4a1. The data clerk enters the patient name or ID of the patient and search the patient 4a2. The system displays the patient data. 4a3. The data clerk updates patient data. 5a. If the data clerk makes error while enters the data, the system displays error message. 5a1. The data clerk clicks an ok button. 5a2. The system inform the data clerk to re-enter patient information

Table 7: Description of Laboratory Test order Use Case

This use case is required to meet F4 requeriment I mentioned on the functional requeriment section.

Use Case ID	UC_4
Use case Name	Order Laboratory Test
Primary actor	Physician
Summary description	The use case describes the process used to order Laboratory test/ investigation
Pre condition	The physician is log in to the system
Post condition	Test order is registered.
Main success scenario	1. The physician wants to order laboratory test. 2. The system displays the main menu screen. 3. The physician search and select investigation order list. 4. The system displays the test/ investigation order form. 5. The physician selects the type of test to be done and submit to laboratory department. 6. The Use case end.
Alternative path	None

Table 8: Description of Laboratory Test Result

This use case is required to meet F5 requirement I mentioned on the functional requirement section

Use Case ID	UC_5
Use case Name	Laboratory Test Result
Primary actor	Laboratory Technician
Summary description	The use case describes the process used to record laboratory test result.
Precondition	The Laboratory Technician is log in to the system
Post condition	Laboratory Test result is registered.
Main success scenario	1. The laboratory technician wants to register laboratory test result. 2. The system displays the test request form. 3. The laboratory technician fills laboratory test results on the laboratory order entry form and click submit button. 4. The system submits laboratory test result to outpatient department. 5. The system saves the data. 6. The Use case ends.
Alternative path	3a. If the laboratory technician makes error while enters the data, the system display error message. 3a1.The laboratory technician clicks an ok button. 3a2.The system informs the laboratory technician to re-enter the data.

Table 9: Description of Generate Report Use Case

This use case is required to meet F6 requeriment I mentioned on the functional requeriment section.

Use Case ID	UC_ 6
Use case Name	Generate Report
Primary actor	Laboratory Technician
Summary description	The use case describes the process used to generate report.
Precondition	The user has authentication to generate report.
Post condition	The user generates report from the system.
Main success scenario	1. The Laboratory Technician wants to generate report. 2. The system display the main screen 3. the user select the report menu 4. The system displays a report form that contains different report options (monthly quarterly, annually). 5. The user select type of reports needed. 6. The system generates the selected report. 7. The Laboratory Technician print the result. 8. The use case ends.
Alternative path	None

Table 10: Description of Maintain User Account Use Case

This use case is required to meet F7 requeriment I mentioned on the functional requeriment section

Use Case ID	UC_ 7
Use case Name	Maintain User Account
Primary actor	System Administrator
Use case description	This use case describes how the administrator maintains the user account.
Precondition	The administrator should register as an authorized administrator.
Post condition	The administrator maintain user account/manage the system
Main success scenario	1. The System administrator wants to maintain user account. 2. The system displays the login screen. 3. The administrator enters user name and password. 4. The System displays the user account form. 5. The administrator performs create new user, update or delete user account. 6. The System validates the information that the administrator enters. 8. The Use Case End.
Alternative path	3a. If the administrator username or password is not valid, an error message is displayed. 3a1. The administrator clicks an ok button. 3a2. The administrator is returned to login screen and re-enter user name and password.

.

4.3.4.2 Activity Diagram

Activity diagrams are one of the important modeling artifacts used in UML is the activity diagrams that are used to model sequence of actions as part of the process flow. It is used to model sequence of actions to capture the process flow actions and its results. It focuses on the work performed in the implementation of an operation and the activities in a use case instance or in an object (41). The following major activity diagrams were designed according to the use case and how the system should function, which are Patient Registration, Laboratory Test Order, Laboratory Test Result and maintain user account.

In addition, an activity diagram to show the general workings of the system is also presented.

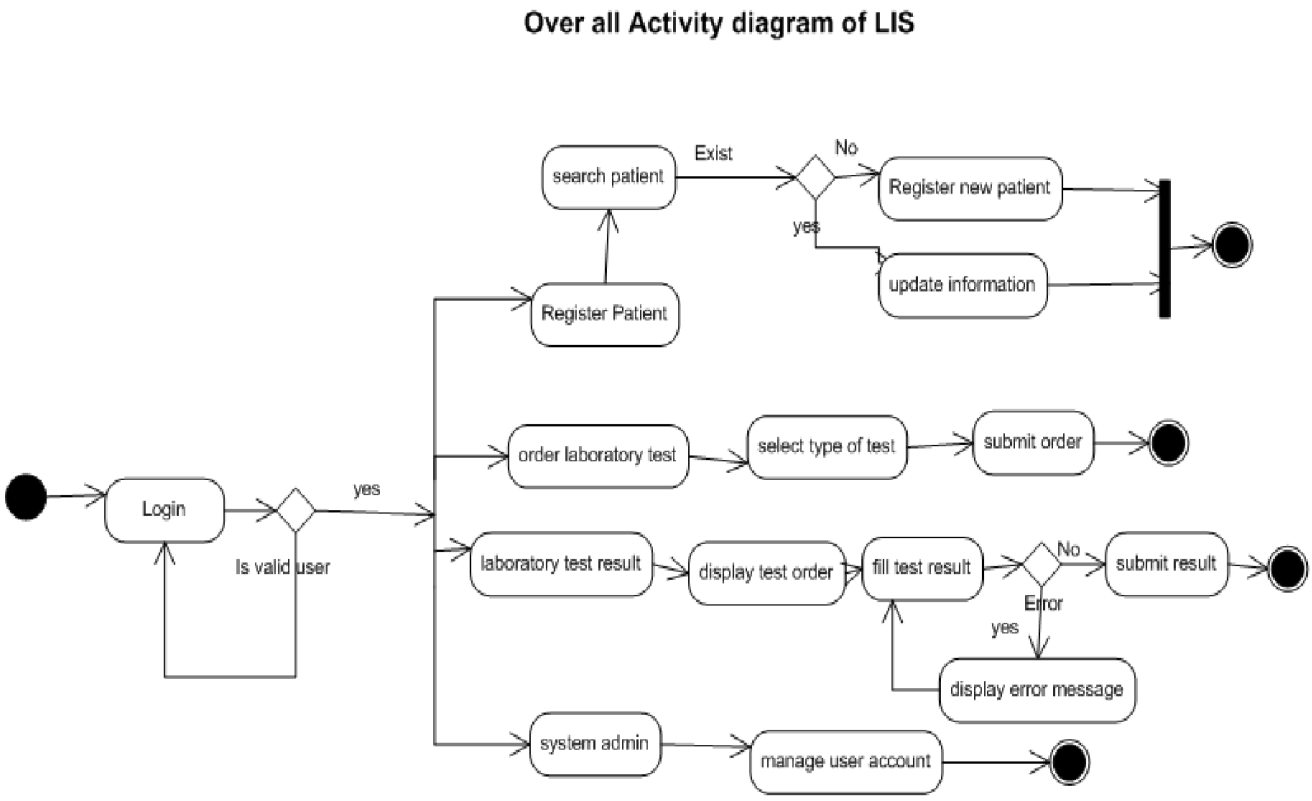


Figure 3: Overall Activity Diagram of LIS

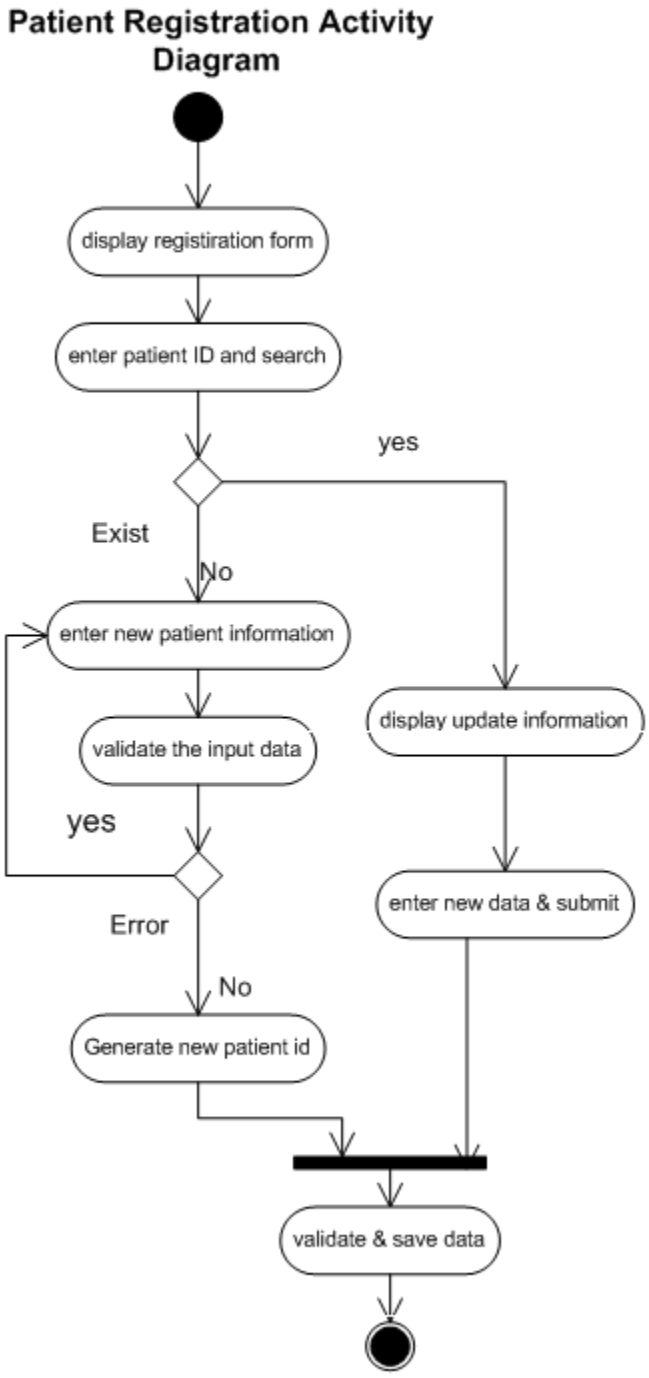


Figure 4: Patient Registration Activity Diagram

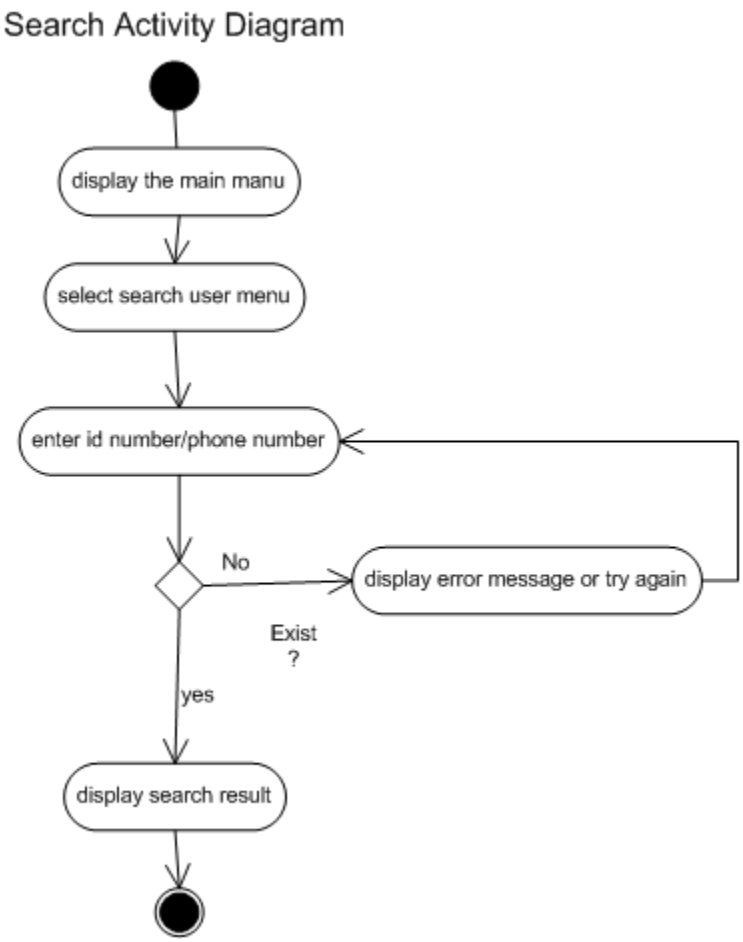


Figure 5: Search Patient Activity Diagram

Laboratory Test Order activity diagram

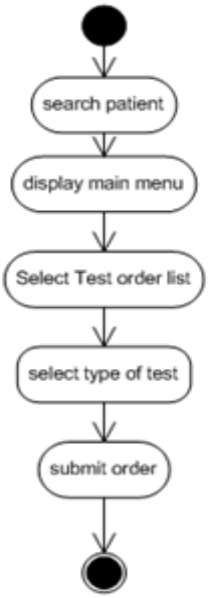


Figure 6: Laboratory Test Order Activity Diagram

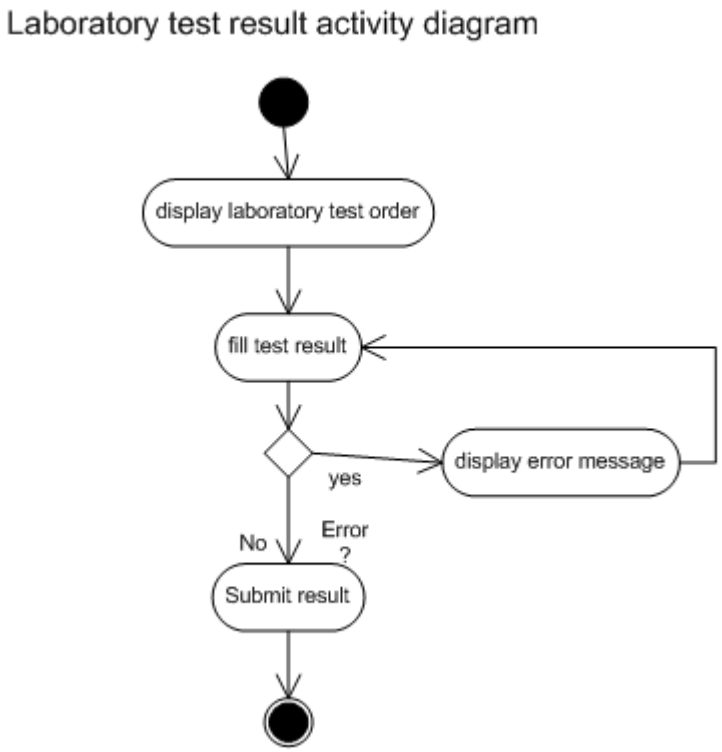


Figure 7: Laboratory Test Result Activity Diagram

Generally this requirement analysis document is important to explain the existing system, identified problems, describe the overall process and the task related to the project being on progress as well as how the proposed system expressed using functional model use case and dynamic model Activity diagram.

4.3.5 Design Model

The Unified Modeling Language (UML) has been chosen as the standard tool for describing the end products of the design activities. The documents generated in this language can be universally understood (24).System design model is one of the formal ways of designing the data that are used and created by any business system. This shows the objects or people, the places, or things about which information is captured and the relationship among each other. Object-Oriented approach is used for analyzing and designing the system. This approach is selected because it has an advantage of modularity, extensibility, reusability as well as maintainability.

4.3.5.1 Class diagram

Class diagram is an integral part of the unified modeling language. Class diagrams are used when developing an object-oriented system model to show the classes in a system and the associations between these classes. It can be used so as to provide a general overview of the system objects and their interactions. An association is a link between classes that indicates that there is a relationship between these classes. So, each class may have to have some knowledge of its associated class (attribute) and the actions that class performs (operations). These attributes, operations are found together in a single block of box during the designing of the class diagram(40). The following table shows the identified classes with respect to their description.

Table 11: Description of Classes identified

No	Class Name	Description
1	Person	A Class that Helps to Hold behavior & Information about the Persons' Objects.
2	Physician	A Class that Helps to Hold behavior &Information about the Physician Objects.
3	Laboratory Technician	A Class that Helps to Hold behavior & Information about the Laboratory Technician Objects.
4	User Account	A Class that Stores users account behavior & Information for the Administrator Physician, Laboratory Technician, Data Clerk
5	Laboratory Test Order	A Class that Stores All Laboratory Test Order objects.
6	Laboratory Test Result	A Class that Store All Laboratory Test Result Objects.
7	Data Clerk	A Class that stores behavior & All Patient Information.

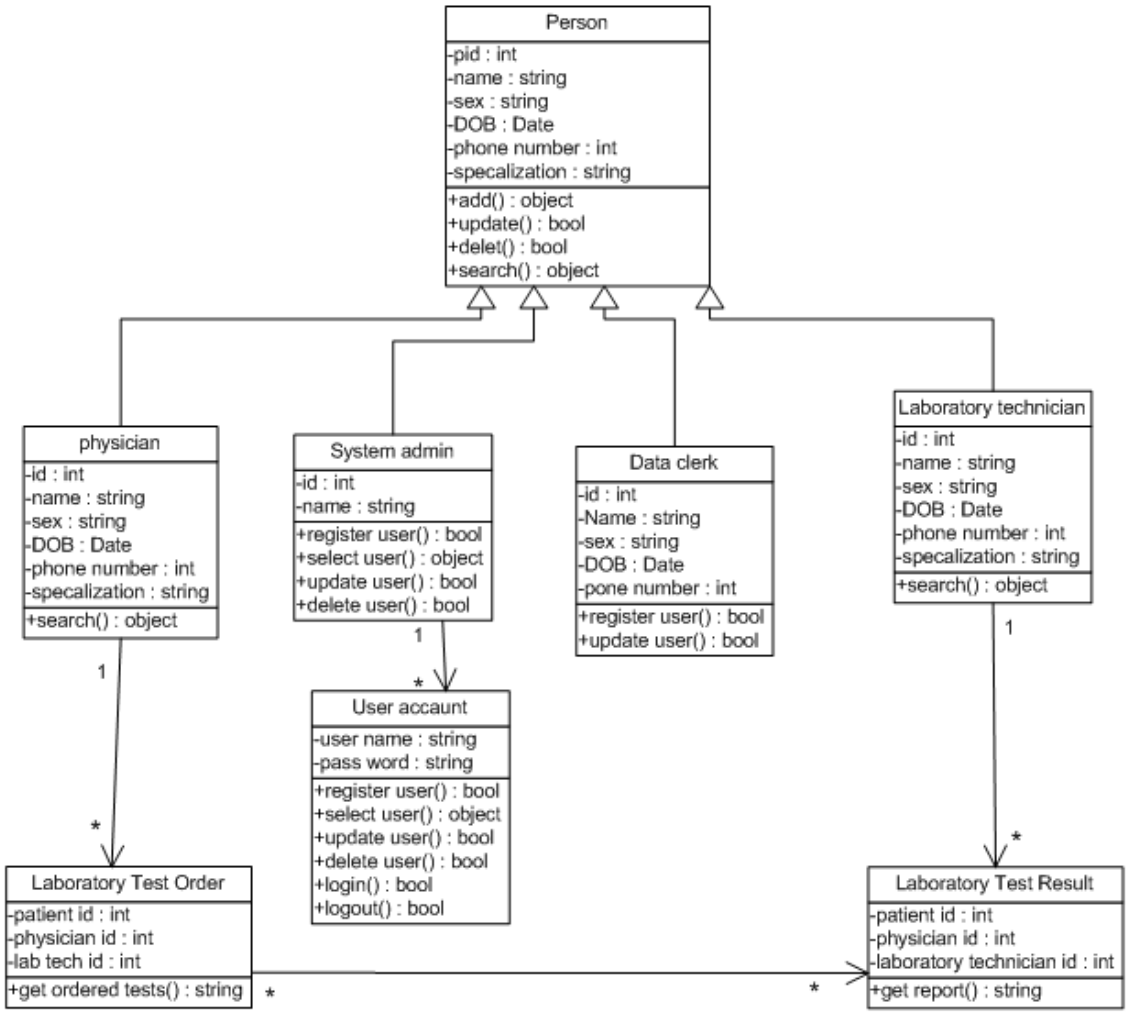


Figure 8: LIS Class Diagram

4.3.5.2 Persistent Model

Most functionality in LIS deals with data. Hence this section discusses the data that is stored persistently. Database system is designed to store data about the messages transmitted between users. Persistent data about users themselves required to be stored so that they can be authenticated and let them communicate each other. Also the laboratory order the physician send to the laboratory technician and the respond that contains the result of the investigation must be stored so that we would be able to generate timely reports as desired.

The persistence model diagram shows the specific data with the corresponding class that is stored in the database, as the user account stores (user name and password), person stores (PID, Full Name, Gender, DOB, phone No), system Administrator (user ID, Name), Laboratory Technician (PID, specialization), physician (PID, Specialization), Laboratory test result (Report).

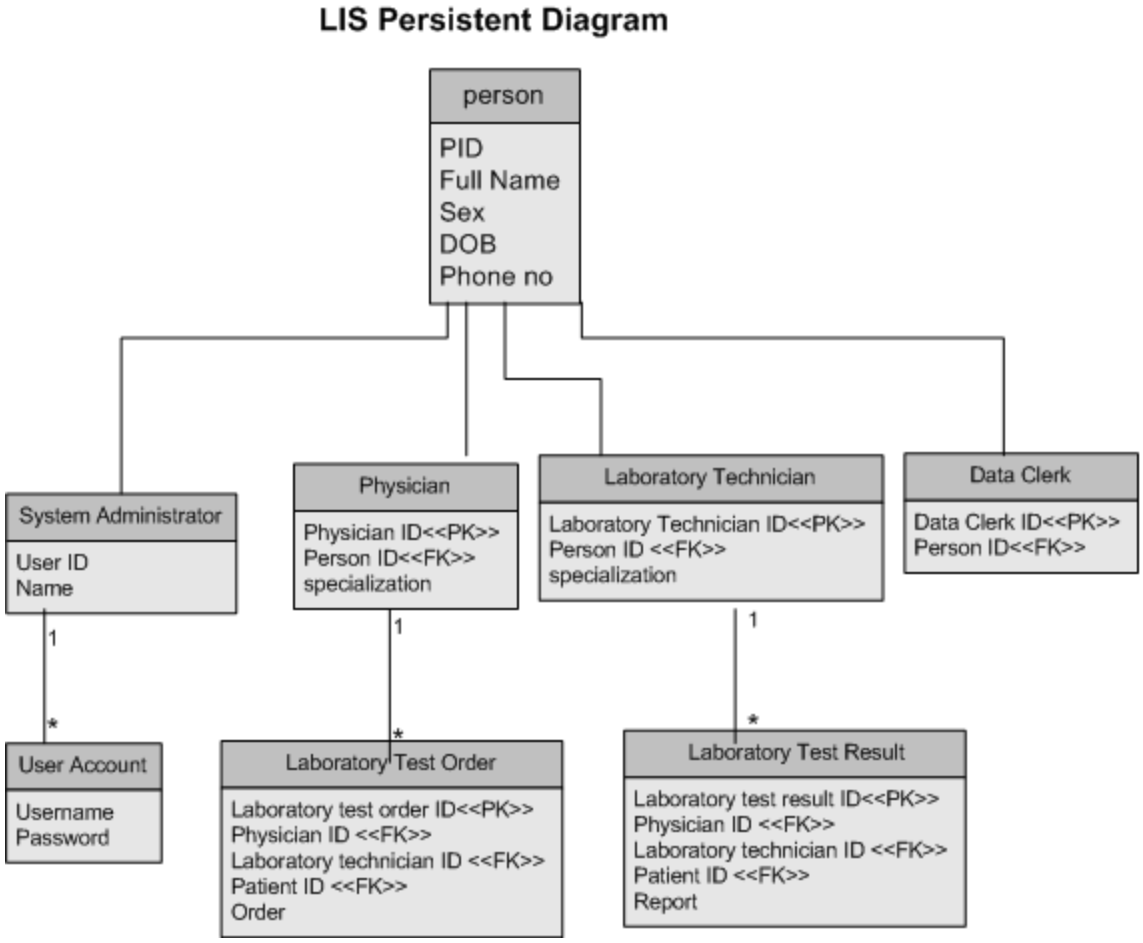


Figure 9: persistent diagram

4.3.5.4 System Deployment Diagram

A UML deployment diagram depicts a static view of the runtime configuration of hardware nodes and the software components that run on those nodes. UML deployment diagrams show the hardware for your system, the software that is installed on that hardware, and the middleware used to connect the disparate machines to one another (40).

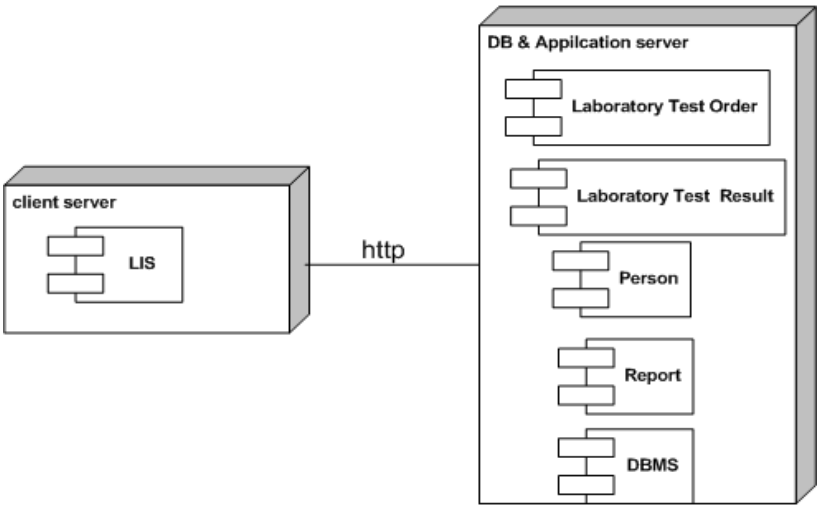


Figure 10; LIS Deployment Diagram

Generally this design document is important to explain as how proposed system, expressed using object model class diagram, deployment diagram and persistent model. As this describes how the proposed system architectural organization and implementation.

CHAPTER FIVE

IMPLEMENTATION AND RESULT

5.1 Overview

In this section of the project implementation, different user interfaces designed, results of the evaluated system have been discussed and described. Following this phase the design of the system was progressed into development of the new system using Joomla, PHP and MYSQL as database management system.

5.2 Major Function of the System

The major functions of the system are registering patient information, update patient data, search patient data, send laboratory request, receive laboratory result and generate report. Sample pseudo code of the LIS presented below.

Patient Registration

```
If (first time entry)
{
   Load registration form
   Card Number = check whether is Card Number is unique
    First Name    = check whether the entered text is less than 34 characters
   Father Name    = check whether the entered text is less than 34 characters
   Grand First Name    = check whether the entered text is less than 34 characters
  Phone = check whether I/p phone number is 12 digit
   Gender = check whether I/p gender has a valid value
    Address = check whether I/p address is filled
    DOB   = check whether I/p is correct date format
 }
 If (all check results == true)
   {
      Generate SQL insert queries
       Connect to database
       Pass queries to database
  If (any query fails)
        Display error message
      Else display registration complete message
}
Else {
 Enable update patient record
}
```

Laboratory test order

```
 If (logged in as physician)
{
  Load lab test order form
    Check the selected test list
    Click send
 }
Else {
Must login as the physician to access the test order form
}
```

Laboratory Test result

```
If (logged in as lab tech) {
     Load lab test result form
       Fills the requested fields
          Check
            if (the fields are filled correctly){
                    Enable submit successfully
                            }
               Else {
                    Display error message (“please fill the form correctly”)
                            }
Else
{
Must login as lab tech to access the lab test result form
}
```

5.3 Sample Prototype Interface

User interface is an implementation part of a system interface that the system uses. The user interfaces are designed in a way that is easier and can be adoptable with ease to the user. The design of this system involves different working models (prototype) of the interfaces that the system uses. The diagram below provides an architectural view of how each user in the system is allowed to use and access different functionalities and data entry usage based on their own administrator assigned privilege (40). Below you will find different user interfaces:

User Interfaces of the Laboratory Information System

Home Page

The home page provides the different information .The tabs that are found at the top lead to different locations and provide different functions. Most importantly in order to get the required services from the system the user must login into the system and each user before logs into the system must have the appropriate password and username and privilege assigned by the administrator.

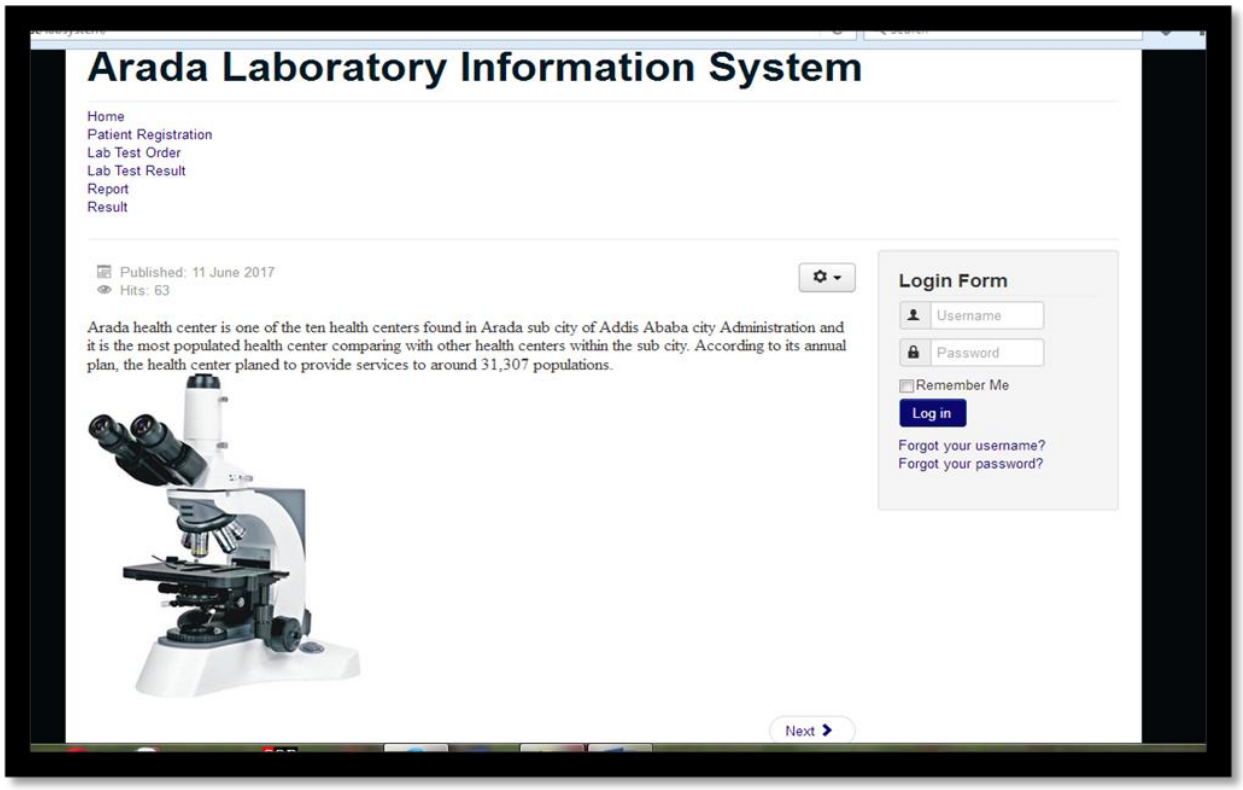


Figure 11: Home Page Interface

Registration page

The registration user interface is used to update and register new patient personal information. Thus the data clerk can access the different functionalities that are required from the system.

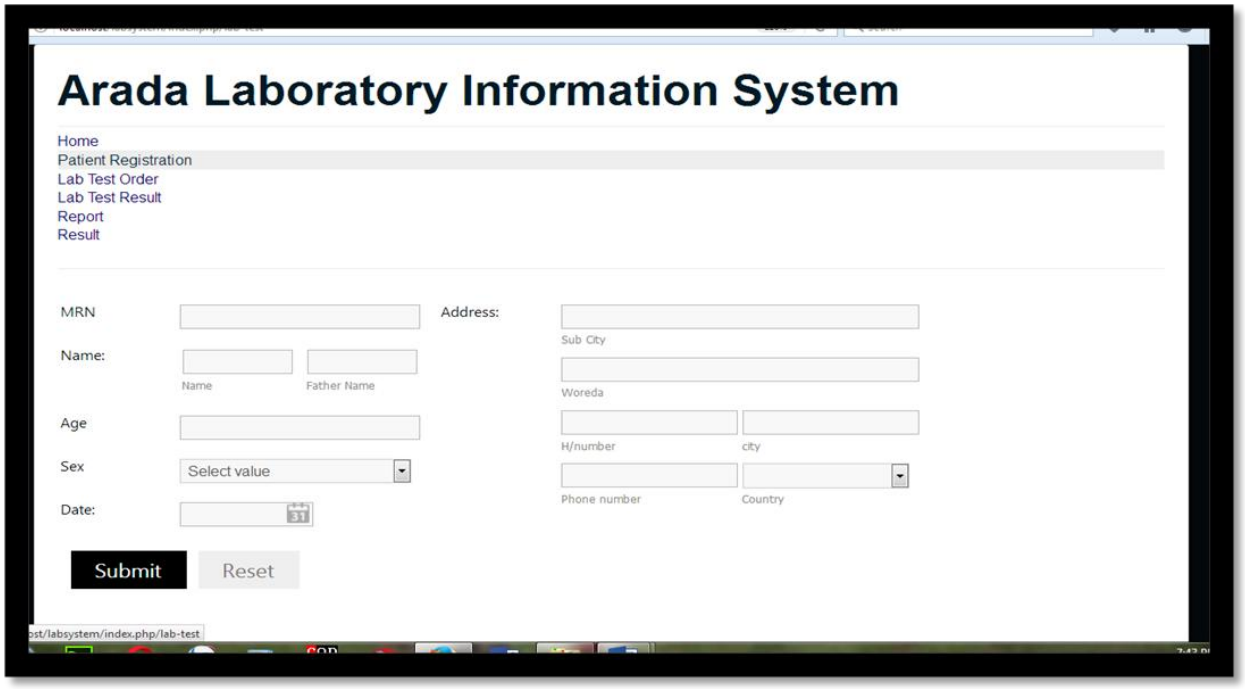


Figure 12: Patient Registration Interface

Laboratory Test order page

Laboratory Test order interface is used to request different laboratory test .Thus the Physician can access the different functionalities that are required from the system.

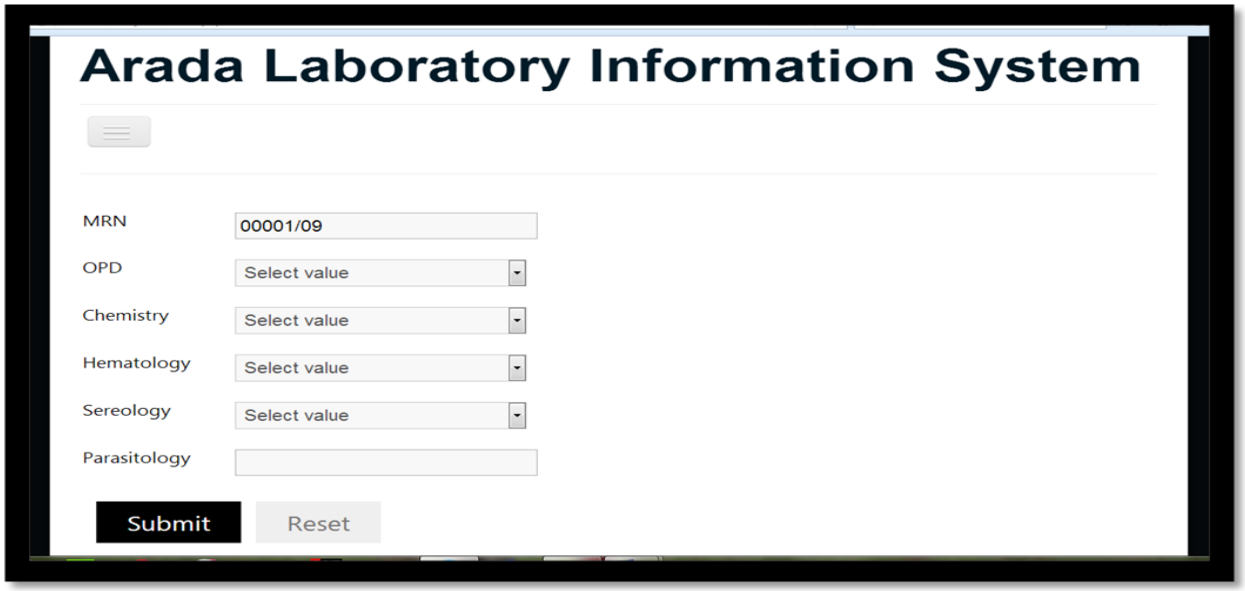


Figure 13: Laboratory Test Order Interface

Laboratory Test Result page

The laboratory test result interface is used to submit different laboratory test result to the sender with its reference range the reference range used by the health center is taken from national guideline. A reference interval is the range of results expected for healthy people (42).

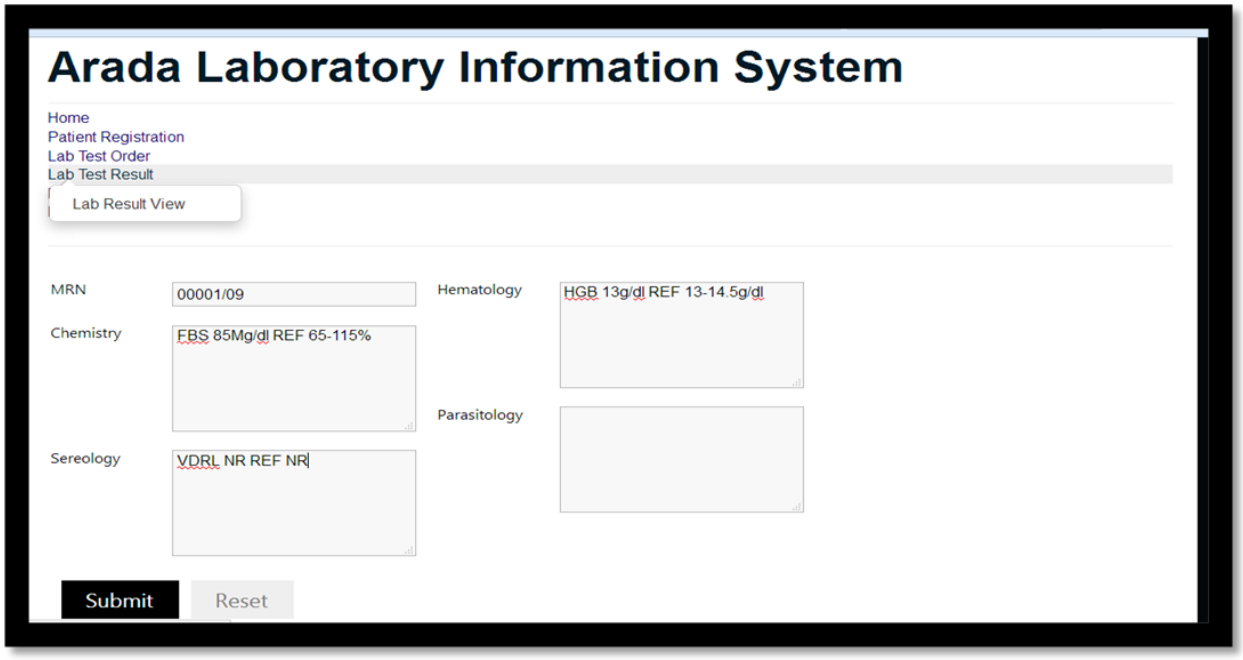


Figure 14: Laboratory Test Result Interface

Report page

This user interface enables users to view the required report based on the report need, weekly, monthly, quarterly and annual reports can be generated using the system. The report generation interface can only be accessed to the concerned bodies and the type of report to be generated depends on the organizations authentication provided during registration.

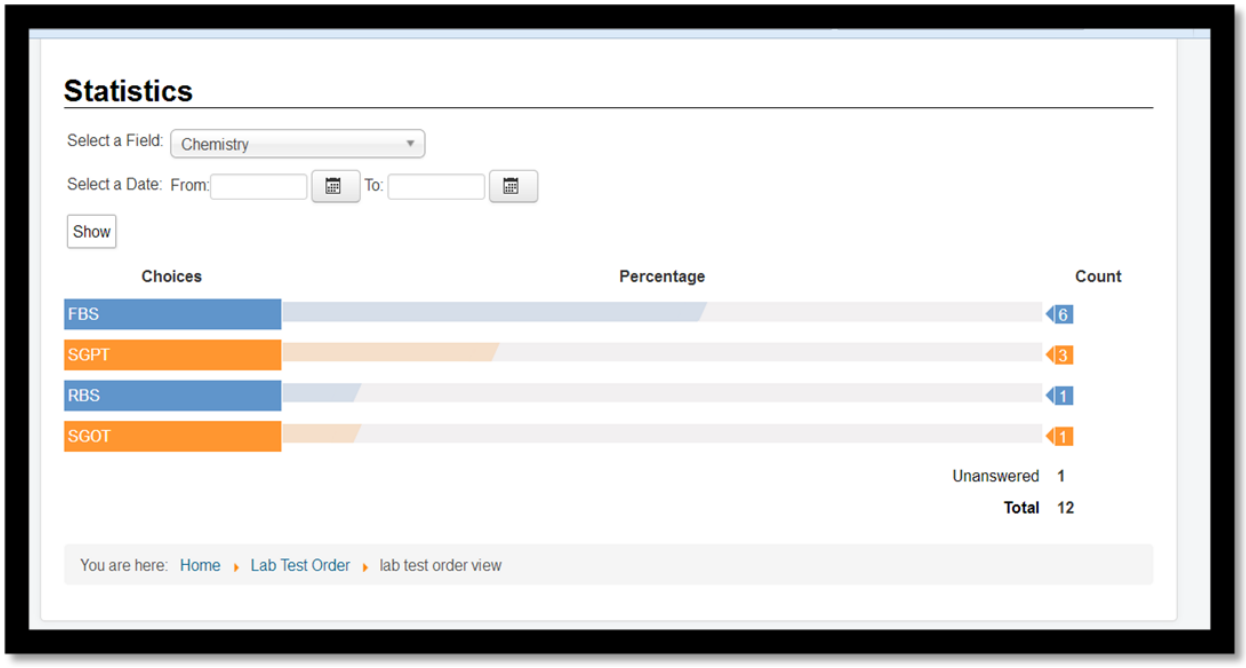


Figure 15: Report Interface

5.4 Testing and Evaluation

The goal of the Lickert Scale test was to determine the acceptability and relevance of functionality of laboratory information system. The evaluation often refers to the question of how well users can understand the system functionality. The evaluation of the interface usability is an important aspect of software design and development (43). The evaluation of the interface for the laboratory information system is used a method of questionnaires with 10 major usability criteria to evaluate the interface for the system developed. The table mentioned below was developed to collect the required response from the users to help in assessing and evaluating the user interface for the newly developed system. The questionnaire was modified after being adopted from Nielsen, Jakob which is used to evaluate user interface evaluation (44).

Table 12 : System Evaluation for Laboratory Information System.

No	**Question of evaluation**	**Strongly Disagree** (1)	**Disagree** (2)	**Neutral** (3)	**Agree** (4)	**Strongly Agree** (5)
1	The system provides adequate registration format	0	0	1	4	5
2	I thought the system is easy to use	0	0	0	2	8
3	The system saves entered data properly	0	0	0	4	6
4	The instructions were easy to follow	0	0	0	5	5
5	There is no unnecessary format available in the interface	0	0	0	5	5
6	Overall interaction to the system is good	0	0	0	5	5
7	The system provides secured and reliable information	0	0	2	5	3
8	The interfaces are visible and clear	0	0	0	6	4
9	There is uniformity in the system interface	0	0	2	5	3
10	The user interface is easy to follow	0	0	0	6	4
		Average result		5%	47%	48%
		Total agree value			95%	

The results of the responses above are taken based on the Likert Scale to check for the functionality of the system. The results show that none of the respondents disagreed options as presented to evaluate the functionality of the components of the developed system. Almost all respondents agreed on the functionality of the system except for the question 1 one user and for questions 7 & 9 two users each asked on the overall interaction of the system and system security responded neutral. Generally the result shows that the developed system functionality is efficient and appropriate to be used to facilitate the laboratory service.

To summarize system evaluation test according to the Likert Scale 95 % of the respondent have agreed that the system has good and clear informational and functional explanation regarding the major functionalities of the system. During testing the system some professionals suggest that it will be easy to access the system if the result page has a separate interface for each laboratory unit.

5.5 Discussion

Laboratory Information System (LIS) refers to the computerization of the laboratory system or automation of secretarial physical activities associated with the processing of laboratory results to improve accuracy and turnaround time of results. Automation of laboratory activities removes the element of manual reporting, increases productivity and allows access to display data for analysis (4).

Arada Health Center has no automated Laboratory information system. This project has tried to design and develop LIS based on the requirement gathered from the study participants. The designed system has a capability to register patient information, retrieve data, and update data, to reduce workload of laboratory professional and help to generate report easily.

The newly designed system in comparison to the previously existing paper based manual system can minimize the various time and resource consuming business process in Arada health center. The new system can also provide easily accessible information or reports that are crucial to the administrative decisions.

It has been discussed that medical laboratories form the backbone of health systems, as test results are critical for diagnosing diseases, guiding treatment, determining drug resistance and identifying diseases of public health significance through surveillance (3).

The researcher has also confirmed that the automation of laboratory activities shall solve the problem of illegible hand writing in records (Transcription error), lack of confidentiality in storing and retrieval of patient data.

Laboratory information system provides more efficient and better performance as compared to manual system. The manual system undergoes several tasks like patient registration, document retrieval and generating report which consumed more time until replaced by button clicks of the laboratory information system that enables for easy data registration, storage, retrieval, processing and information utilization through electronic access. The newly developed laboratory information system was evaluated based on the set of predefined objectives and expected functionalities. The designed interfaces are totally graphics oriented and user friendly.

The laboratory information system has been commonly used in the hospitals with higher work load; however this laboratory information system is different in that it is tailored to be used to the level of health center.

The evaluation is based on the fact that data requirements were collected and analyzed successfully before the development of the system. The design and development of laboratory information system was further accomplished with patient registration, laboratory test order register and return back laboratory test result to physician and generate report functionalities in the system.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Considering the importance of the laboratory information system for the health center the researcher in this project has identified the problem of ordering a number of laboratory test order papers for single patient, the long time for data retrieval, transcription error and illegible hand writing that has been encountered while using paper based documentation.

Consequently the researcher has designed an integrated laboratory information system that can capture a number of laboratory test orders with a single interface used by the physicians and the laboratory technicians in the exchange of information for ordering of laboratory tests and receiving the results back to the physicians and generate report.

The method used in this project was a qualitative study combined with a design oriented iterative (incremental) approach following an object-oriented system development. The techniques used for analysis and design in this project were use case diagram, activity diagram, class diagram, deployment diagram and persistent model. Microsoft Visio 2007 was also used to design the system.

The functional requirements of the system were gathered from the health professionals, data clerk and higher officials in the health center who have direct contact to laboratory department. Also, system modeling was done using unified modeling language (UML). Requirement analysis has been done using document review and interview with the staff that has directly contact with the laboratory department and come up with the identification of the following use cases.

The system was developed using Joomla. Testing and evaluation was done to describe to what extent the system is usable by using Likert Scale. The result of the test shows that almost all of the respondents were happy with the system.

The developed system solves the problem of data integration and can capture a number of laboratory test order forms with a single interface used by the physician and the laboratory technician in the exchange of information for ordering laboratory tests and receiving the results back to the physician. This makes the laboratory data to be easily manageable and accessible by health professionals and decision makers. Usability test has been done and discussion was made with users in order to determine functionality, effectiveness and acceptability of the project and almost all of the respondents accepted the prototype. Regarding the functionality, the system produces reliable data and hence avoids the problem that used to occur by the manual system.

6.2 Recommendations

After completing the project the researcher provided the following recommendations for practice and future work.

Recommendations for practice

- The health centers should be able to provide the hardware that is required to deploy the system and the necessary infrastructural support during the implementation of the system like electric power in the health center.
- The Regional Health Bureau, the Arada Sub city health office, the Arada health center management committee and other concerned government & non-government organizations need to give attention to this valuable project and support for its deployment.

Recommendations for future work

- The system should be upgrade to the full-fledged patient management system.

REFERENCE

1. Delhi N. Guidelines for good clinical laboratory practices (GCLP). Indian Counc Med Res New Delhi. 2008;
2. Strategic N. Sample country Laboratory Services National Strategic Plan. 2008;1–42.
3. Systems M. What is a LIMS - a laboratory toy , or a critical IT component ? Dr Alan McLelland Institute of Biochemistry , Royal Infirmary , Glasgow The Laboratory ' s Function The International LIMS Conferences. Available from: https://www.revolvy.com/topic/Laboratory information management system&uid=1575
4. World Health Organization. Laboratory quality management system: Handbook. Laboratory quality management system: handbook. 2011. 248 p.
5. Weekly P. Health Information Systems in India. 2012;21(35).
6. Enock Yonazi, Tim Kelly NH and CB. The Transformational Use of Information and Communication Technologies in Africa. E-Transform Africa. 2012;56–69.
7. Ontario Hospital e-Health Council. Laboratory Information System Integration. 2006;(November).
8. Tagger B. An Introduction and Guide to Successfully Implementing a LIMS (Laboratory Information Management System). 2011.
9. World Health Organization. Laboratory Quality Standards and Implementation. 2011.
10. EHNRI. Polytech LIS for Ethiopia. 2011.
11. I-TECH. Upgrading Laboratories towards WHO-AFRO Laboratory Accreditation. 2010;2010–1.
12. Yu E. Information Systems (in the Internet Age). 2004;
13. Asemahagn MA. Health professionals' Challenge in using ICTs to manage their Patients the case of Hospitals in Addis Ababa, Ethiopia _ HIMSS. 2016.
14. Cornford T, Shaikh M. Introduction to information systems Economics , Management ,. 2013;

15. Andrés Fernández. ICT and Health. Newsletter. 2010;(12):12.

16. Haverkort. Information Systems : Introduction and Concepts. Press MIT. 2011;1–40.

17. Almunawar MN, Anshari M. Health Information Systems (HIS): Concept and Technology. Int Conf Informatics Dev. 2011;

18. WHO. Health Information. 2008;(June).

19. Efraim Turban, R. Kelly Rainer REP. Chapter 14 Information System Development. Introd to Inf Technol. 2005;461.

20. Brinkkemper S. Method engineering: Engineering of information systems development methods and tools. Inf Softw Technol. 1996;38(4 SPEC. ISS.):275–80.

21. Investigation I. Selecting a development approach. 2008;1–10.

22. Giantdino B, Booch G, Rumbaugh J, Jacobson I, Matter F, Rumbaugh J. Unified Modeling Language User Guide, The. 1998.

23. Kling R. Four Paradigms of Information Systems Development. 1989;32(10).

24. Dathan B, Ramnth S. Object-Oriented Analysis and Design. 2010.

25. Nyasulu PS, Paszko C, Mbelle N. A Narrative Review of the Laboratory Information System and Its Role in Antimicrobial Resistance Surveillance in South Africa. 2014;(August):692–6.

26. Faculty TA, Monu R, Fulfillment IP. Design and implementation of a basic laboratory information system for resource-limited settings design and implementation of a basic laboratory information system for resource-limited settings. 2010;(May).

27. Infirmary R. Laboratory information management system. Technology. 2009;1–7.

28. Systems M. Management Systems,. 2007;

29. Harrison JP, Mcdowell GM, Harrison JP. The role of laboratory information systems in healthcare quality improvement. 2008;

30. Services M of H and S. National Public Health Laboratory. 2012;(October).

31. Mbah H, Ojo E, Ameh J, Musuluma H, Negedu-Momoh OR, Jegede F, et al. Piloting

laboratory quality system management in six health facilities in Nigeria. PLoS One. 2014;9(12):1–14.

32. Blaya A, Shin SS, Yagui M, Contreras C, Cegielski P, Yale G. Reducing Communication Delays and Improving Quality of Care with a Tuberculosis Laboratory Information System in Resource Poor Environments : A Cluster Randomized Controlled Trial. 2014;9(4).

33. Sarah Andersson MM. Logistics System Design for Botswana. 2009;(March).

34. Waruhari P, Ng'ang'a J. Implementation of a web-based laboratory information system (lis) in a hiv care and treatment program: kenyatta national hospital comprehensive care centre (knh ccc) case. 2009;(Knh Ccc):1079–87.

35. Shiferaw W. Data exchange interoperability framework For laboratory information system (LIS) and electronic health record (EHR) of two hospitals in addis ababa. 2013;

36. Alemu G. Designing an Electronic Medical Record System for Amanuel Hospital. 2014;

37. Ribeiro VV, Travassos GH. Testing Non-Functional Requirements- Lacking of Tehnologies or Researching Opportunities.pdf. 2016;15.

38. Priestly M. Practical Object-Oriented Design with UML. 2000.

39. Jacobson I. Use-case 2.0. A Guid to succeding with use case. 2011;(December).

40. Ambler SW. The Elements of UMLTM2.0 Style. 2005.

41. Bhattacharjee AK, Shyamasundar RK. Activity Diagrams: A Formal Framework to Model Business Processes and Code Generation. J Object Technol. 2009;8(1):189–220.

42. Paper W, Chemistry C. The Need to Harmonize Clinical Laboratory Test Results. 2015;(July).

43. Jackson D. Web Usability Testing Guidance. 2015;1:2–5.

44. Block AJ. Introduction To Usability. 1994;105(3):649a–649.

Annex-I Consent Form

Good Morning / Afternoon

Introduction

My Name is Debritu Kebede, I am a postgraduate student at Addis Ababa University School of Information Science and School of Public Health in Health Informatics Program. Currently I am collecting data to carry out the project as a partial fulfilment of the requirements for M.Sc. in Health Informatics programm with **t**he title "Laboratory information system for Arada Health Center: Using a Design Approach**" .**The aim of this preliminary survey is to identify functional and non-functional requirements for the system.

This project will improve the turnaround time (TAT) for laboratory service , quality of data and reduce transcription error as well as benefiting the laboratory technician, the government and the community at large. The interview will take 15-20 minutes and I would like to assure you that the information that you provide will completely be kept confidential and will be used only for the project purpose. Your honest responses will be used as an essential input for the defining of requirements which is important for designing and developing the Laboratory Information System.

As a participant of this survey, please note that you may seek clarification on any of the questions and you may withdraw from the survey at any time you wish to do so.

Thank you for your kind cooperation and taking the time to complete this survey

Are you willing /voluntary to participate in this survey? Circle your response 1. Yes 2. No

Name of data Collector _____

Signature_____

Date_____

Annex II- Interview guide

A. Recipients: Users of LIS program (Health professionals)

1. What are the main challenges in your laboratory?

_____

_____

2. How did you communicate laboratory results to the physician?

_____

_____

3. How many tests did you perform per day Can you please explain it in terms of workload?

_____

_____

4. Did you face misdiagnosis complain due to transcription error?

_____

_____

5. Please describe your general opinion on the existing laboratory documentation

_____

_____

6. Do you have a unique patient identification number in your laboratory? If you have please describe.

_____

_____

7. How do you record & keep the patient data confidential?

_____

_____

8. How do you prevent loss of patient data due to theft or other incidents?

_____

_____

9. How do you evaluate turnaround time (TAT) of laboratory result?

_____

_____

10. How do you retrieve laboratory data for revisiting patients?

_____

_____

11. How do you solve transcription error of laboratory result?

_____

_____

12. How did you generate laboratory reports periodically?

_____

_____

13. Is there any specific task in laboratory system that you feel is difficult & can be supported through LIS?

_____

_____

B. Interview Guide for Higher Officials

1. How many laboratory professionals do you have?

_____

_____

2. Did you get laboratory report timely?

_____

_____

3. Did you use the laboratory reports for reagent procurement plan?

_____

_____

4. Did you face misdiagnosis complain due to transcription error?

_____

_____

5. What are the challenges you have got when you use the manual system?

   _____

   _____

6. Does the health center have a plan to develop laboratory information system?

   _____

   _____

7. How is the connectivity at the health center?

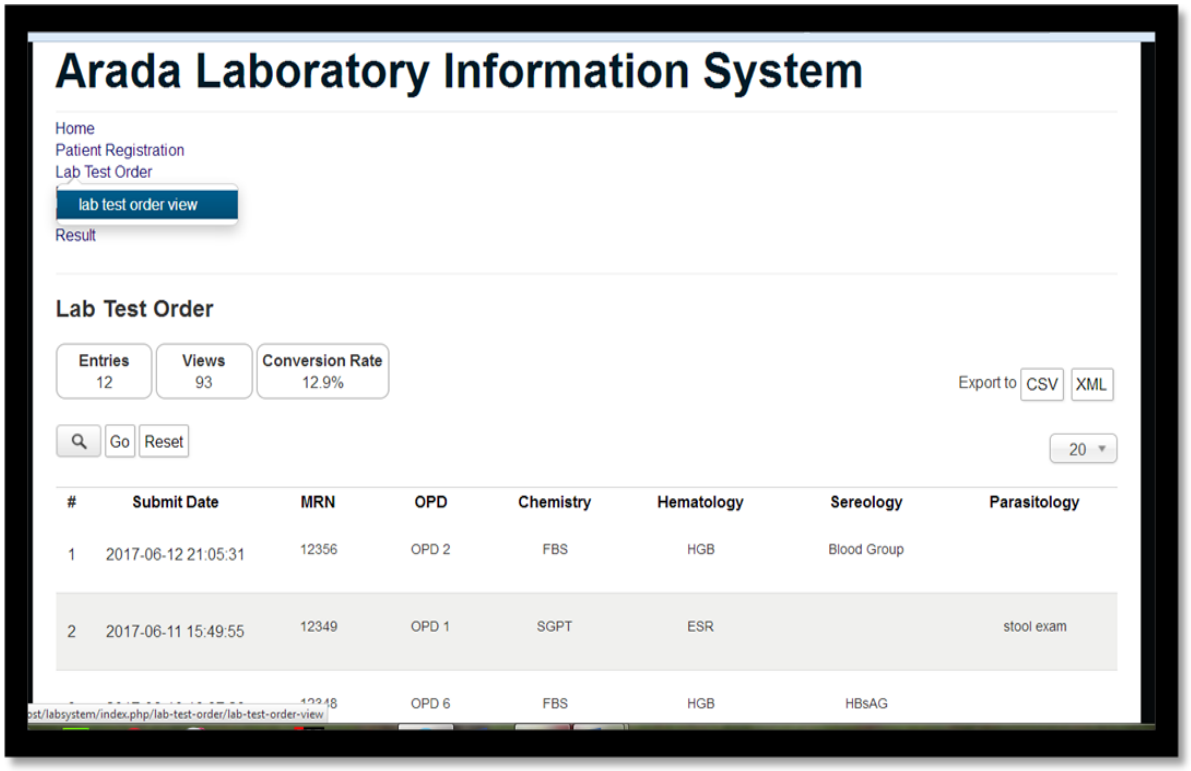
   _____

   _____

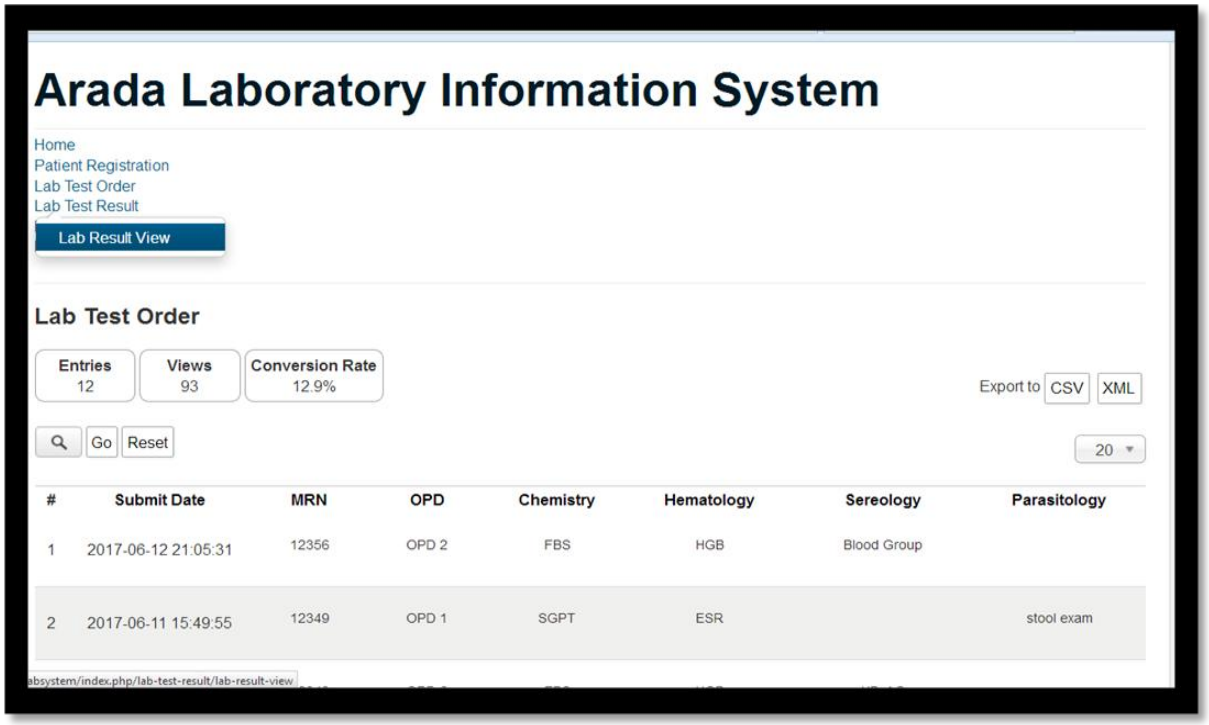
System Evaluation Question

The Likert Scale represents system evaluation questionnaires according to functional requirements of the system given their response being 5 to strongly agree,4 to agree,3 to neutral,2 to disagree and 1 to strongly disagree in terms of the functional requirements being met or not.

No	**Question of evaluation**	**Strongly Disagree** (1)	**Disagree** (2)	**Neutral** (3)	**Agree** (4)	**Strongly Agree** (5)
1	The system provides adequate registration format					
2	I thought the system is easy to use					
3	The system saves entered data properly					
4	The instructions were easy to follow					
5	There is no unnecessary format available in the interface					
6	Overall interaction to the system is good					
7	The system provides secured and reliable information					
8	The interfaces are visible and clear					
9	There is uniformity in the system interface					
10	The user interface is easy to follow					
		Average result				
		Total agree value				

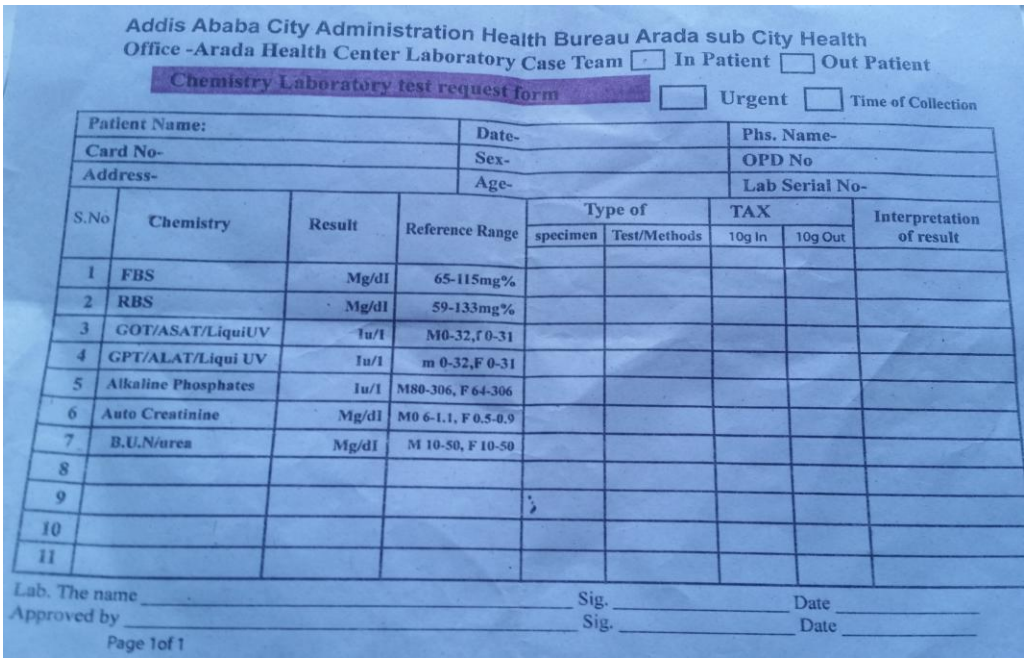


Laboratory Test Order View Interface



Laboratory Test Result View Interface

Annex III-Existing Laboratory Test Order Format and Log Book



Addis Ababa City Administration Health Bureau Arada sub City Health Office -Arada Health Center Laboratory Case Team ☐ In Patient ☐ Out Patient

Chemistry Laboratory test request form ☐ Urgent ☐ Time of Collection

Patient Name:	Date-	Phs. Name-
Card No-	Sex-	OPD No
Address-	Age-	Lab Serial No-

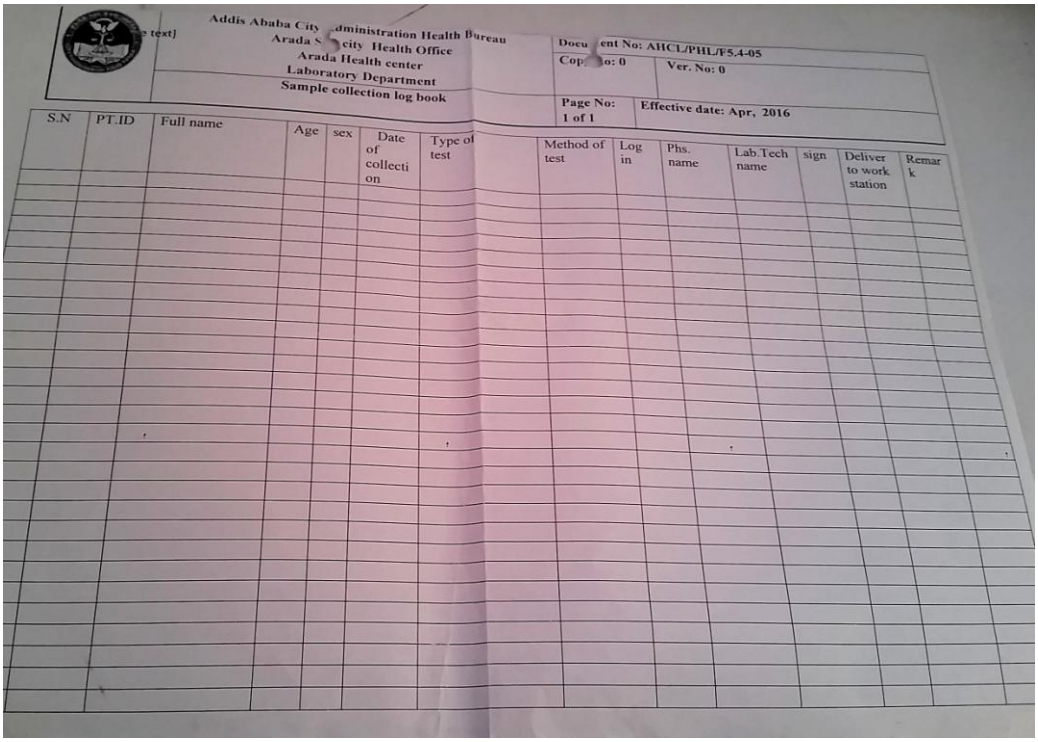
S.No	Chemistry	Result	Reference Range	Type of specimen	Type of Test/Methods	TAX 10g In	TAX 10g Out	Interpretation of result
1	FBS	Mg/dl	65-115mg%					
2	RBS	Mg/dl	59-133mg%					
3	GOT/ASAT/LiquiUV	Iu/l	M0-32,f 0-31					
4	GPT/ALAT/Liqui UV	Iu/l	m 0-32,F 0-31					
5	Alkaline Phosphates	Iu/l	M80-306, F 64-306					
6	Auto Creatinine	Mg/dl	M0 6-1.1, F 0.5-0.9					
7	B.U.N/urea	Mg/dl	M 10-50, F 10-50					
8								
9								
10								
11								

Lab. The name _____ Sig. _____ Date _____

Approved by _____ Sig. _____ Date _____

Page 1of 1

Chemistry laboratory test order form



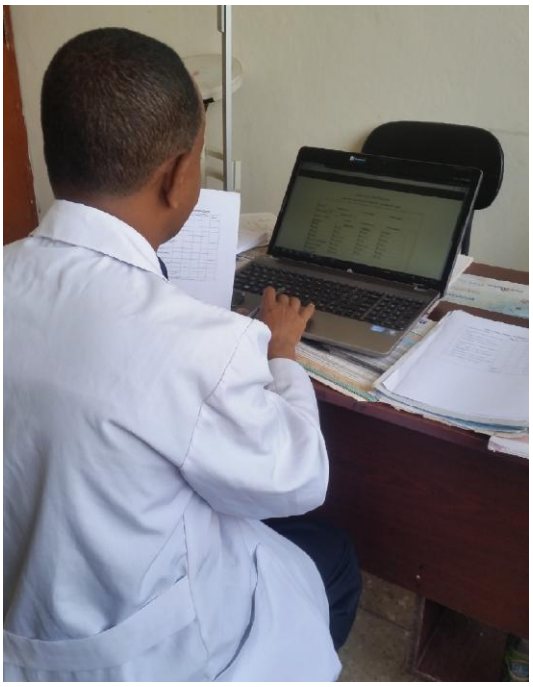
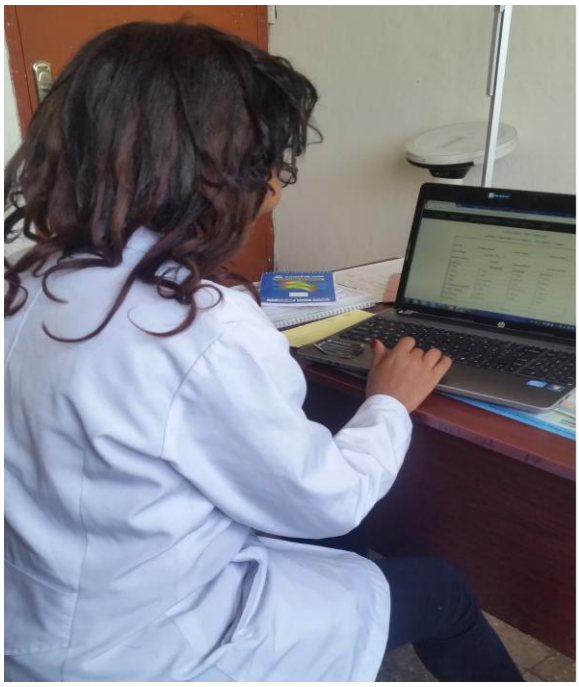
Addis Ababa City Administration Health Bureau
Arada Sub city Health Office
Arada Health center
Laboratory Department
Sample collection log book

Document No: AHCL/PHL/F5.4-05
Copy No: 0
Ver. No: 0
Page No: 1 of 1
Effective date: Apr, 2016

S.N	PT.ID	Full name	Age	sex	Date of collection	Type of test	Method of test	Log in	Phs. name	Lab.Tech name	sign	Deliver to work station	Remark

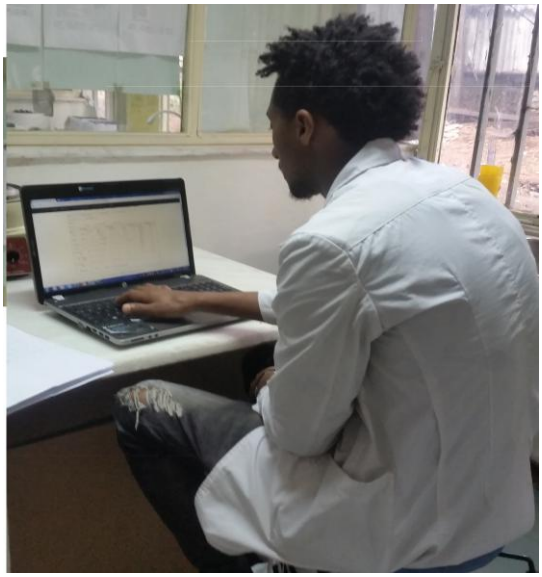
Sample Collection Log Book

Annex IV- Picture taken during system evaluation

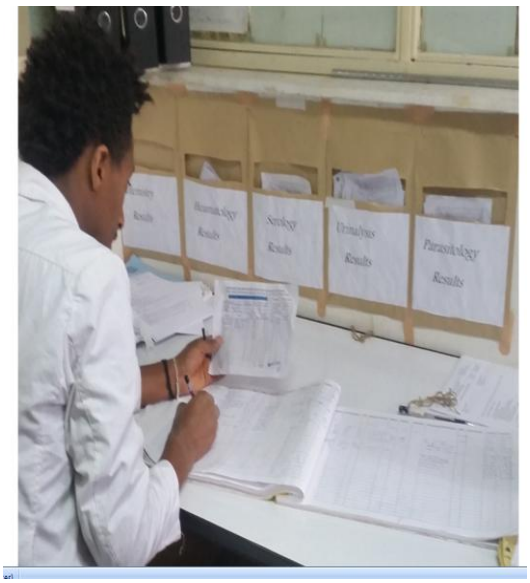



Arada health center physicians while testing the developed system

Arada health center laboratory technician While testing the developed system



Arada health center laboratory technician while doing manual result record



Declaration

I, the undersigned, declare that this project work is my own original work and effort and that it has not been presented for a degree in any other university, where other sources of information have been used, they have been duly acknowledged.

Name Debritu Kebede

Signature _____

Date _____

This project has been submitted for examination with my approval as university advisor.

	Signature	Date
Tibebe Beshah (PhD)	_____	_____
Yimer Seid (MPH)	_____	_____